



Digital life and crime trends in the global south: on the impact of increased Internet use on opportunities for crime

Vida digital y tendencias delictivas en el sur global: sobre el impacto del mayor uso de Internet en las oportunidades para la delincuencia

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Abstract

This study addresses a gap in the literature about crime trends by exploring how increased Internet usage and the digitalization process fundamentally reshape criminal opportunities. We analyse the relationship between human agency and social structure, demonstrating how the “virtual world” alters social habits in a manner that creates a fertile ground for cybercrime. Multilevel Linear Modelling (MLM) was employed to estimate participation in Property Damage Crime (PDC) based on individual typologies. Additionally, we extend our analysis to account for seasonal patterns and forecast trends through the Holt-Winters (HW) method, considering the effects of the Covid-19 pandemic. Findings show that the adoption of digital technologies has transformed social interactions and criminal behaviour, reducing participation in street crimes while increasing exposure to online offenses, especially among teenagers. The results also revealed that variability in the trajectory of crime participation is explained by individual typology and Internet access. Moreover, cybercrimes significantly increased after March 2020 compared to violent crimes. These emerging patterns and trends underscore the need for specialized law enforcement agencies to address cybercrimes and online threats, and to promote prevention and education strategies.

Keywords: Technology, Internet, digitalization process, participation on crime, cybercrime.

Resumen

Este estudio aborda una laguna en la literatura sobre las tendencias delictivas al explorar cómo el aumento del uso de Internet y el proceso de digitalización reforman fundamentalmente las oportunidades para la delincuencia. Analizamos la relación entre la agencia humana y la estructura social, demostrando cómo el “mundo virtual”, al alterar los hábitos sociales, crea un terreno fértil para el ciberdelito. Se empleó el Modelo Lineal Multinivel (MLM) para estimar la participación en los delitos de daños a la propiedad (PDC) en función de las tipologías individuales. Además, extendemos nuestro análisis para tener en cuenta los patrones estacionales y prever tendencias mediante el

método Holt-Winters (HW), considerando los efectos de la pandemia de Covid-19. Los hallazgos muestran que la adopción de tecnologías digitales ha transformado las interacciones sociales y el comportamiento delictivo, reduciendo la participación en delitos en las calles y aumentando la exposición a delitos en el ciberespacio, especialmente entre los adolescentes. Los resultados también revelaron que la variabilidad en la trayectoria de participación delictiva se explica tanto por la tipología individual como por el acceso a Internet. Además, los ciberdelitos aumentaron significativamente después de marzo de 2020 en comparación con los delitos violentos. Estos nuevos patrones y tendencias subrayan la necesidad de contar con agencias especializadas en la aplicación de la ley para abordar los ciberdelitos y las amenazas en línea, así como promover estrategias de prevención y educación.

Palabras clave: Tecnología, Internet, proceso de digitalización, participación en delitos, ciberdelincuencia.

Introduction

Criminology, which involves a variety of other disciplines and fields of study to incorporate new ideas and solve current and emerging problems (Garland, 2002), has established itself as a discipline often focused on patterns of regularities and trends in deviant behaviour, as well as the factors associated with them. Rather than symptoms, these patterns provide clues about social movement, about the direction in which society is heading.

In order to identify regularities as spatiotemporal trends and the factors associated with them, it is necessary that the sources used, such as criminal records and others from police organizations or victimization surveys, are of high quality (Baumer & Lauritsen, 2010; Ruback & Greenberg, 1984; Wittebrood & Junger, 2002) and reliable (Boivin & Cordeau, 2011).

Despite limitations, criminal records have important advantages over other sources of crime data that allow us to analyse the prevalence in time-space of criminal phenomena. With this kind of data, it is possible to estimate future trends in reported crime through forecast time series data and, in some cases, to incorporate factors into the statistical models to find associations related to structural or ecological dimensions (Borowik et al., 2018, Cohen, 1981, Feng et al., 2019). Above all, these analyses, in addition to describing phenomena, have an even more relevant trait, namely: they contribute enormously to the empirical testing of criminological theories (Duncan et al., 2003, Matsueda et al., 2006, Sampson et al., 1997).

This study examines the impact of changes in everyday life derived from the use of the Internet and the digitalization process on many aspects of society, including but not restricted to the way in which people communicate, access information, and spend their free time¹. These changes have also had an impact on crime, victimization, and criminal behaviour, and have pushed scholars to direct their attention towards unravelling the complex interplay of behavioural, attitudinal, and environmental elements that drive individuals to perpetrate online offenses or to become victims of

¹This study has been conducted as part of the project "GamerVictim, sobre el análisis fenomenológico y victimológico, y respuesta jurídica a las conductas problemáticas en torno a comunidades digitales asociadas a videojuegos", financed by the PROGRAMA PROMETEO 2023 - CIPROM/2022/332, which seeks to investigate and propose normative solutions to harmful conducts arising related to digitalization, video games and social networks.

online crimes (Borwell et al., 2021, Holt & Bossler, 2008).

The police database used in this research will help us to analyse to what extent Internet access negatively influences the incidence of crimes classified as property damage crime (PDC)² Our hypothesis is that increased access to the Internet changes the use of individuals' free time (more time devoted to the use of social networks, online games, chatting, texting, etc.) creating a new routine and lifestyle based on more online interactions which in turn generates an impact on crime, reducing PDC within a specific age group and increasing cybercrime.

This new pattern in behaviour is associated with a reduction in the traditional social relationships that characterize the occurrence and participation in crimes, particularly among teenagers, a group that is more exposed to the use of new technology as a form of entertainment and leisure. On the other hand, access to the internet also creates a new environment for crime to be committed, that is, the virtual world becomes a fluid space where offenders leverage their ability to reach potential victims with little protection or lacking capable guardianship, especially for scams and frauds (Chen et al., 2017) or use of malicious software (Holt et al., 2016). This phenomenon may have been aggravated by the Covid-19 pandemic, whether because of new forms of contact and interaction, or due to a change in the way people use services and make transactions.

Technology, Everyday Life and Crime

The relationship between technology and crime has been studied from numerous perspectives (McGuire & Holt, 2017; Osterburg & Coates, 1967; Savona, 2004). Macro-level social changes have been treated both as a factor that can favour delinquency through situations facilitating crime occurrence, mainly in the urban environment, and in relation to crime prevention, such as the incorporation of innovations at different levels of the criminal justice system (Grommon, 2018; Hankin et al., 2011; Harris, 2007).

Considered a central element in explaining the occurrence of crime by some criminological theories, the context of criminal opportunity is a mediating factor in the relationship between technology and crime rates. In the second half of the 20th century, criminological approaches directly highlighted how social changes resulting from the incorporation of new technology into society were associated with new patterns of criminality and victimization (Cohen & Felson, 1979; Holt & Bossler, 2008; Markwick et al., 2019).

From the outset, the routine activities perspective has been used to explain changes in crime trends over time and from a situational point of view, in which the opportunities element imposes itself as a potentiating factor in the space-time convergence of crime (Cohen & Felson, 1979). In this regard, it is technology that can make all the difference between whether a certain crime occurs or not, because it makes crime a feature of our social organization.

This relationship between technology, opportunity, and criminal trends has also been present in the crime trend most studied in relation to technology in recent decades: the so-called 'crime drop'.

²Literal translation of the typology of the data used: "Destroying, disenable or deteriorating something belonging to another person; using violence against the person or serious threat; using inflammable or explosive substances, if the fact does not constitute a more serious crime; against the assets of the Federal Government, State, Municipality, public service concessionaire or mixed economy company, for selfish motive or with considerable damage to the victim".

We must begin by recognizing that although on occasions it has been seen as something monolithic, this phenomenon contains a variety of tendencies that, moreover, do not occur in the same way in all places, crimes, or cohorts (Aebi & Linde, 2010). Along with other reasons given to explain the downward trend in some forms of crime, especially property crime and some forms of violent crimes linked to it, in Western countries since the mid-1990s, opportunity factors linked to technology have been noted (Baumer, 2011; Rosenfeld, 2009). Thus, in the well-known “security hypothesis”, Farrell and colleagues (2011) conclude, based on routine activity theory and the increase in investment in security in most countries in the 1990s (Clarke & Newman, 2006), that changes in the quantity and quality (technological) of security reduced vehicle theft (Farrell et al., 2011). However, the scope of the theory was later extended to other forms of crime related to the hypothesis, such as theft (Thompson, 2014) and burglary (Tilley et al., 2015); (Tseloni et al., 2017), and then to any crime drop believed to be impacted by technology.

Recently, an important group of authors has emerged, who have also begun to apply the opportunity perspective to examine the relationship between crime drops, and other recent trends in delinquency, and the great technological revolution, the digitalization process, that began to manifest itself from the nineties and especially from 2000 onward. This makes sense, especially if we consider all the advances in recent years that have not only allowed greater accessibility but have also created a completely new universe of digitalization, in general, and regarding changes in habits related to new ways of interacting (Llinares, 2011), which altered our way of understanding what was happening in the context of the physical and real world.

The question is that, on the one hand, and as many authors have pointed out, the Internet provides new ways for potential criminals to come into contact with the victims (Eck & Clarke, 2003; Llinares, 2011), and creates a new context in which traditional crimes (fraud, identity theft, and child pornography) can take new and specific forms (Caneppele & Aebi, 2019; Clarke, 2004). On the other hand, digitalization and the Internet have created a new leisure lifestyle at home and changed young people’s habits, indirectly affecting some street crime rates. The underlying idea is to reverse Cohen and Felson’s argument for the 1970s which set out that what increased opportunities, and with it the unexpected increase in crime, were technological changes that led to social changes such as the popularization of the automobile and increased mobility, or the placement of ATMs and increased cash availability. In contrast, what decreased opportunities in the 1990s could be technological changes that led to reductions in mobility and opportunities on the streets and increased time in houses (Aebi & Linde, 2010).

Studies have emerged that have connected this social change to new patterns of criminality. For example, the appearance of digital entertainment at home, especially among young people who previously spent more time on the streets and were involved in delinquency. Kerr (2005), for example, linked the changes in crime rates during the 80s and 90s with technological leisure (television, video games, computers), pointing to a relationship between these changes in social habits, especially the increase in the amount of time spent at home by some groups (young people, men with economic possibilities), and crime (Kerr, 2005). More recently, Miró-Llinares and Moneva (2019) related some of the “drops,” specifically that of juvenile delinquency in the mid-90s, with digitalization, particularly the increase in time spent at home by young people (Miró-Llinares & Moneva, 2019; Baumer et al., 2021).

Other investigations have concluded that the increase in computers, the Internet, and video games inside houses have produced a new form of digital socialization among young people, which has contributed to changes in crime rates. Exposure to the virtual environment has increasingly become a risk factor. Increased amount of time online, particularly among adolescents, is strongly associated with the phenomenon of cyberviolence. While exposing this group to the risk of becoming victims of cyberbullying, fraud, and other forms of virtual crimes, it also leads people to engage in hostile behaviours online (Costello et al., 2022).

In this sense, one can discuss how time and space displacement, with the advent of the Internet and digitalization, affect the use of time and people's safety, putting them at greater exposure and vulnerability to becoming victims of crimes. In addition, this technology can exponentially favor the offender since he/she is now capable of reaching his victims more easily and with a low risk of being identified or captured given the anonymity of virtual contacts and absence of strong legal regulation (Newman & Clarke, 2013).

In fact, from a macro perspective, Cohen and Felson (1979) argued that the nation's prosperity affected routine activities in ways that increased criminal opportunity (Cohen & Felson, 1979). From an individual point of view, we are facing a reality in which technology is associated with trends in crime and victimization through a new way of using time. These changes brought on by technology would contradict explanations arising from the lifestyle-exposure theory put forth by Hindelang and colleagues (1978). Additionally, Cohen and colleagues (1981) identified five factors that mediate the relationship between demographic characteristics and predatory victimization: exposure, proximity, attractiveness, guardianship, and definitional properties of crimes themselves (Cohen et al., 1981).

Here, we propose to analyse the effect of technology on individual behaviour, in particular the way in which all these recent advances that encompass the digitalization process have altered people's use of time in a way that has reduced their exposure as victims and their participation in street damage crimes. On the other hand, we examine how this same technology was responsible for creating a new virtual environment that enhances the action of criminals, which may have been devastating due to the social changes imposed by the Covid-19 pandemic that began in March 2020 affecting the entire planet.

Research questions, data, and methodology

To expand the scope of the theoretical discussion presented above, the current research seeks to examine the agency-structure relationships between technology, changing behaviour, internet usage time and opportunity to commit crimes from a temporal perspective across the global south context. Specifically, we seek to identify how changes in internet access have different effects according to individual typology and also city size, which are reflected in property damage crime participation over time. In doing so, we also examine how the "virtual world" creates a window of opportunity for committing cybercrimes, without the need for spatio-temporal physical convergence of offenders and victims. In fact, our hypothesis is that the occurrence of the Covid-19 pandemic was a natural experiment that provided even more of these opportunities in the virtual world, proven by the growth of cybercrimes, while street crimes experienced the opposite trend.

Data

The data used in this study is composed of two nested datasets representing the offenders and events of PDC reported to police in the Minas Gerais State for the period 2012 to 2022. The Offender data set has in total 133,777 people and has information at the individual level and the Event data set is a database of crimes reported by cities in Minas Gerais. This criminal data officially known as the Register of Social Defense Events (REDS) corresponds to police reports filed with the Military Police of Minas Gerais (PMMG) and the Civil Police (PCMG). Also, we used a database containing the time series of cybercrimes from REDS to explore the relationship between Internet access, crime, and the Covid-19 pandemic. Additionally, we use information from Anatel³ regarding the total accesses to fixed broadband (also known as Multimedia Communication Service - SCM). The database also includes broadband entry data in schools according to the Broadband in Schools Program and the installation of backhauls according to the National Broadband Universalization Plan.

Study area

Minas Gerais is in the southern region of Brazil, sharing borders with Espírito Santo, Bahia, Goiás, Mato Grosso do Sul, São Paulo and Rio de Janeiro states. With an estimated population of 20.539.989 people in 2022, according to Instituto Brasileiro de Geografia e Estatística - Censo 2022. Minas Gerais has a demographic density of about 35,02 inhabitants per square kilometre in an area of almost 586,513.983 square kilometres⁴. There are 853 cities in Minas Gerais and the Human Development Index is 0,774. It is important to note that, in Brazil, municipalities are not defined by size, but according to Article 18, § 4, of the 1988 Brazilian Federal Constitution.

Variables

Table 1 presents the descriptive statistics of outcome and independent variables. All variables were computed for the 853 cities in the Minas Gerais State, the Southeast Region of Brazil. The main interest of this study was to evaluate the effect of Internet access (time spent on technology) on the rate of participation in property damage crimes, by age group, over time.

The temporal factor considered in this study is essential, as it allows us to capture behaviour changes from the association between the outcome and explanatory variables. Generally, longitudinal data structure consists in observing measures of a given unit (e.g., individuals) over time. In this study, we created 12 typologies of individuals based on their characteristics such as gender, age and race. From these typologies, it was possible to calculate the participation rate in the total composition of PDC by quarter. Thus, it can be said that the panel structure of the data reflects the trajectory (or behaviour) of each typology over time in the proportion of PDC committed within the city where the occurrence was recorded. That is, individuals were categorized into typologies considering information about sex (Male and Female), age profile (Teenagers, Youth, and Adult), and race (White and Non-White). For each combination of these characteristics, their percentage participation in the PDC by quarter and city was calculated.

³Anatel is the Agência Nacional de Telecomunicações

⁴Available at: <https://www.ibge.gov.br/cidades-e-estados/mg.html>.

The data were grouped into quarters to reduce the variability that is very large in the cases of smaller cities where events are scarce. Therefore, to capture the longitudinal effect of the data, the most basic level of observation comprises the participation rate in PDC in the quarter (1, 2, 3, ...41) for each of the typologies (1, 2, 3, ...12) in each city (1, 2, 3, ..., 853). Since not all typologies have percentage participation in all quarters, and in all cities, the database corresponding to this level resulted in a universe of 153,742 observations.

Over time, the participation rate in PDC captures the trajectory in time k of the behaviour of individual typology j in city i . The dependent variable, finally, is a measure of the behaviour over time of the distinct individual typologies in PDC occurring in the city. The higher the participation rate of a given typology at a point in time, the less heterogeneous is the composition of the profile responsible for the crimes, that is, the more homogeneous is the typology that is involved in the crimes. Despite the limitations related to the use of official police data, such as underreporting, biases and all the problems related to different procedures for recording and categorizing cybercrimes, we believe that the measures used in this study can be valuable for understanding crime trends and patterns.

Table 1

Descriptive Analysis

Variable	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Var
PDC participation	11	2059	4556	9164	7305	85212	256627182
City	1	178	412	410.300	614	853	66377.410
Time	0	8	17	18.050	28	40	136.303
Internet Access	2.568	159.930	298.742	365.665	507.487	4216.086	71798.430
Male	0	1	1	0.798	1	1	0.161
Teenager (<17 y)	0	0	0	0.154	0	10	0.130
Youth (18-29 y)	0	0	0	0.332	1	1	0.222
Adults (30+ y)	0	0	1	0.512	1	1	0.250
Race (white)	0	0	0	0.299	1	1	0.210
Population <K	0	0	0	0.289	1	1	0.205
Population 20-50 K	0	0	0	0.181	0	1	0.148
Population 50-150 K	0	0	0	0.239	0	1	0.182
Population 150-500 K	0	0	0	0.1343	0	1	0.116
Population +500 K	0	0	0	0.157	0	1	0.12
Damage Crime Rates	0.002	0.144	0.250	0.319	0.400	1	0.061
Cyber Crime	1530	2147	2739	3407	5071	6570	2556340
Violent Crime	2730	3736	7060	7515	10824	14277	14467726
Theft	1305	1856	3967	4457	6700	9025	6782053
Theft and Robbery of Vehicle	1832	2278	3130	3331	4386	5597	1245149

According to the United Nations Development Programme (UNDP), in the period 2021/2022 Brazil had a Human Development Index (HDI) of 0.754. Minas Gerais, in the same period, according to Instituto Brasileiro de Geografia e Estatística (IBGE), had a higher HDI of 0.774.

This study utilized all individuals from REDS, the official database from Minas Gerais, Brazil, between January/2012 to March/2022, with a total of 133,777 offenders. Regarding the number of occurrences, cities with a population of between 50 and 150 thousand are the largest. All variables shown above refer to Minas Gerais and summarize the statistics of the events during the period of analysis. The total number of observations in the final model was 153,741 crimes.

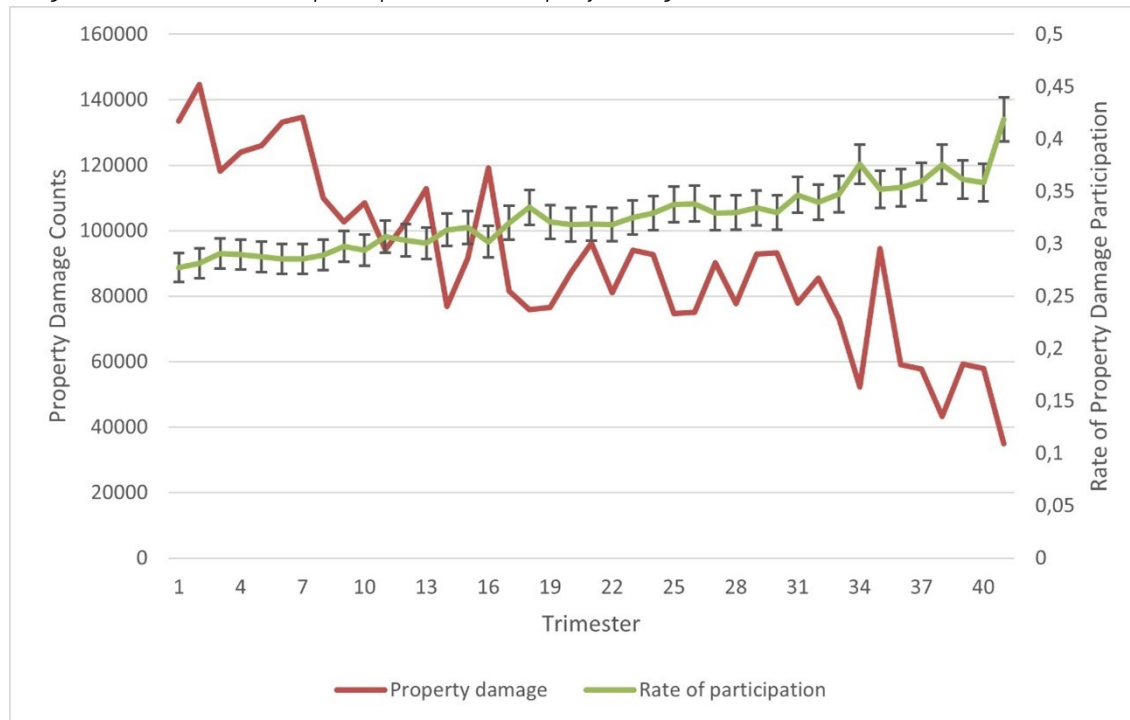
The PDC variable was constructed as a continuous variable. Figure 1 presents two important pieces of information about trends and outcome variables used in this study. On the one hand, it is

observed that throughout the 41 quarters, that is, from January 2012 to March 2022, the absolute number of property damage crimes shows a linear reduction trend over the period, starting from about 140 thousand quarterly occurrences at the beginning of the series to less than 40 thousand occurrences in the last quarter. On the other hand, there is an increase in the average participation rate in PDC, from about 0.27 to over 0.41 at the end of the series. This means that over time, participation in PDC has become more homogeneous across age and gender groups.

This pattern is very interesting and justifies our investigation, as it demonstrates that despite the reduction in PDC, there has been a change over time in the composition of those involved in this crime. Therefore, more important than describing the trend, we are interested here in finding a greater understanding regarding the social structure that may have affected individual behaviour, above all, of a particular group.

Figure 1

Longitudinal trend and rate of participation in the Property Damage Crime (PDC), Minas Gerais, Brazil, 2012 to 2022s



Analytic strategy

Longitudinal studies consist in observing data from the same unit of observation over time. In the case of this study, given the nature of the data, it is not possible to identify the same individual over time. To overcome this limitation, we created a typology of individuals based on their individual characteristics, from which it was possible to calculate the proportion of crimes committed by each of these typologies. With this, it can be said that the longitudinal structure of the data reflects the trajectory of this typology over time in the proportion of PDC committed within the city where the crime was recorded.

In this study, Multilevel Linear Modelling (MLM) was employed for the longitudinal analysis to

estimate the participation in PDC by each typology of individuals. Here, the MLM accounts for three levels of data structure. Level-1 represents the rates of participation in PDC (annually per quarter) for each group of typology of individuals over time. Level-2 represents an individual level with a set of variables that describes demographic characteristics (sex, age group and race). Level-3 in this study represents the city level, with its own set of variables, where the principal variable of analysis is the rate of access to the internet by quarter. Using the same structure of the panel data, we use fixed-effects models that include city, demographic characteristics and time to assess how changes in the rate of internet access (as a proxy of technology) are associated with changes in the participation in property damage crime across 41 trimesters (2012 to 2022). The MLM models were estimated using R-project (version 4.2.1) as well as for the forecasts. The packages used were: lmerTest, nlme, lme4, reclass, merTools, ggplot2, lattice, tidyverse, forecast, lubridate.

We designed our analysis as shown below in Figure 2. The data accounts for the dependency between cities and individuals' observations, which in this case could be observed by trimester (quarter). In fact, using a multilevel model means that each level in the dataset is represented by its own *submodel*, and the regression parameters such as intercepts, slopes, or both are treated as random variables to explain the variation at Level-2 (individual level) and Level-3 (city level) (Ewing et al., 2006; Kwok et al., 2007).

Figure 2

Multilevel Linear Model Scheme



Multilevel linear modelling can be used for the purpose of prediction, it can also be used for the purpose of data reduction, and, as we thought here, can be helpful for drawing out the causal inference.

Final Model – add covariates and interactions

Typically, with models consisting of three or more levels, the next step after adding covariates at Level One (such as time) is considering covariates at Level Two. In the PDC registers, the Level Three covariates of interest are the demographic ones regarding the offenders: age, race, and sex (indicator variables). The age categories were: 17 years old or younger (Teenager); Between 18 and 29 years old (Youth); Older than 29 years old as a reference category (Adult); and white man was a reference category too. Level Three city covariates were Internet access rate; population (separated into five groups/levels: Up to 20 thousand people (reference category); Between 20 and 50 thousand

people; Between 50 and 150 thousand people; Between 150 and 500 thousand people; Over 500 thousand people). We are primarily interested in the effects of an individual typology on the PDC rate affected by internet access and city population over time.

We considered the main effects of city population, internet access rate and demographic variables on the PDC rate. Thus, in the final model we have built Level Three interaction terms using internet access rate and time. The addition to Level 3, covariates and their interactions with time and with internet access rate in the final model appears to provide a significant improvement (likelihood ratio test statistic = 2405.4 on 17 df, $p < .001$) to the Unconditional Growth Model (Model 1).

Results

The first results are from the unconditional model. The estimated mean rate of participation in PDC was 0.51. Random effects estimates showed the following rates of participation in PDC variance estimates: var = 0.0252525 at Level 1, var = 0.01254 at Level 2 (individuals), and var = 0.03929 at Level 3 (cities).

From the variance estimates, 32.7% of the total variability in the rate of participation in PDC is due to differences in time k for each individual j nested within city i , 16.2% of the total variability is due to differences between individuals j in the same city i and, 50.9% of the total variability is due to differences between all 853 cities i . This result supports the hypothesis that most of the variance explained in the trajectory of participation in property damage crime is at the city level, as a function of ecological or structural characteristics at that level of observation. Almost 1/3 of the variability is explained by the characteristics of the individual typology, that is, the sociodemographic profile over time. Finally, the smallest explained proportion of the variance occurs among individuals in the same city, reinforcing the thesis that internally to the city, these typologies would have a smaller explanatory weight in the percentage participation in property damage crimes.

Final model

The goal of this study is to measure to what extent the use of time devoted to the virtual world through an increased amount of people using the Internet can differentially affect individual participation in PDC. As shown by the null model, most of the variability in the average participation rate is due to characteristics at level 3, because of this, in the final model we evaluated this random effect of the Internet access rate for individuals.

The hypothesis is that over time, Internet access associated with a change in individuals' time usage has affected the age groups differently; in particular, compared to adults, teenagers would be much more exposed to this technology and, therefore, would have a lower participation in the PDC over time. Table 2 below presents these results and Figure 5, in Appendix, presents plots of the final model random effects.

Table 2

HLM Parameter Estimates for Fixed and Random Effects

Fixed Effects	Null Model		Model 1		Final Model	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	0.506 **	0.007	0.478 **	0.008	0.543 **	0.007
Time (Level 1)			0.002 **	0.000	0.002 **	0.000
Sex (Level 2)					0.000 **	0.000
Teenager (<17 y)(Level 2)					0.088 **	0.003
Youth (18-29 y)(Level 2)					-0.070 **	0.004
Race (Level 2)					-0.033 **	0.003
Access_tx (Level 3)					-0.056 **	0.003
Population 20-50 K (Level 3)					-0.271 **	0.013
Population 50-150 K (Level 3)					-0.394 **	0.018
Population 150-500 K (Level 3)					-0.429 **	0.036
Population +500 K (Level 3)					-0.449 **	0.064
Time:Access_tx:Youth (18-29 y)					0.000 **	0.000
Time:Access_tx:Teenager (<17 y)					0.000 **	0.000
Time:Access_tx:Race					0.000	0.000
Time:Access_tx:Sex					0.000 **	0.000
Time:Access_tx:Population 20-150 K					0.000	0.000
Time:Access_tx:Population 50-150 K					0.000 *	0.000
Time:Access_tx:Population 150-500 K					0.000	0.000
Time:Access_tx:Population +500 K					0.000	0.000
Random Effects (Trimester 1 reference)	Null Model		Model 1		Final Model	
	Var	SD/Corr	Var	SD/Corr	Var	SD/Corr
Between people from the same city	0.013	0.112	0.018	0.136	0.015	0.121
Within-person residuals over time	0.025	0.159	0.023	0.151	0.023	0.151
Between cities	0.039	0.198	0.050	0.223	0.026	0.162
Rate of change in crime between people from the same city			0.000	0.005/-0.61	0.000	0.005/-0.73
Rate of change in crime between cities			0.000	0.004/-0.44	0.000	0.004/-0.64
Model deviance REML (parameters)	15195.976	(1)	23024.308	(2)	19806.579	(19)
Number of obs:	153741	GROUPS:	individuals -	8027	cities -	853

Notes: **:p-value<0.05; *:p-value<0.10

Although the absolute number of PDC has increased over time, the PDC rate has decreased for the same period. This could be explained by individual typologies and different populations in Minas Gerais cities. The reason for the rate fall should be explained by age group characteristics. It was observed that, controlling for the interaction between internet access rate and time, the PDC rate decreased over time for teenagers and young people. Thus, we conclude that adults have greater participation in PDC than youngsters as illustrated by Figure 3 below.

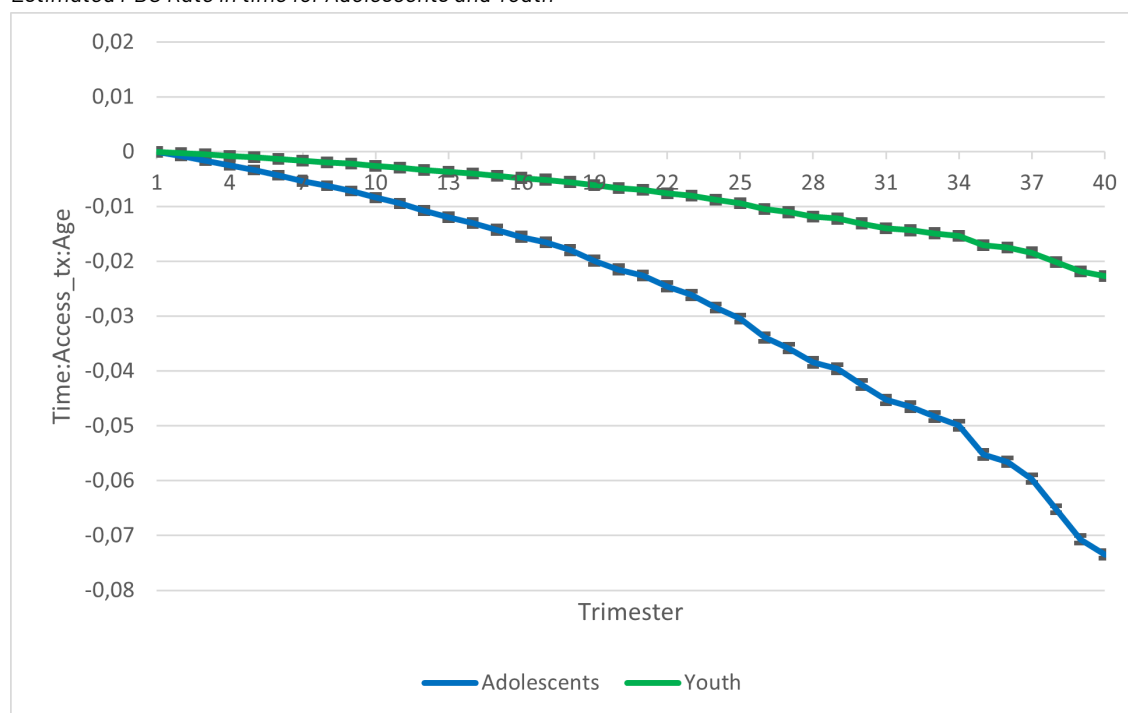
We have sought to demonstrate the relationship between technology and criminal dynamics over time in an area of the global south. By analysing the criminal pattern of PDC from the established typologies, we can perceive how the internet and the widespread adoption of digital technologies has impacted people’s behaviour and their routines with consequences in different dimensions of lives. In particular, we have sought to show that this new way of using time through the digitalization process has altered the traditional social interaction, leisure, work or other activities previously carried out in the physical environment, thereby affecting participation in “street crimes”, especially for teenagers, who are those most influenced by technology.

On the other hand, this same technology provided a shift in time and space, affecting people’s safety, putting them at greater exposure and vulnerability to becoming victims of crimes and exponentially favouring the offender, since they are now capable of reaching victims more easily and

with a low risk of being identified or captured. By opening a “window of new opportunities” with this virtual world, the offender finds specific contexts to act more easily, such as the changes imposed worldwide by the Covid-19 pandemic of 2020.

Figure 3

Estimated PDC Rate in time for Adolescents and Youth



In the final model, we check multicollinearity by using the Variance Inflation Factor (VIF), which measures the correlation and strength of correlation between the predictor variables in a regression model, hence the standard errors and the variances of the estimated coefficients are inflated when multicollinearity exists. The value for VIF starts at 1 and has no upper limit. The mean of the final model VIFs is 1.42463, which is close to 1. This means that there is no evidence of correlation between a given predictor variable and any other predictor variables in the model. Is important to note, as shown in Table 4, that none of the VIFs were more than 5, which reinforces the absence of multicollinearity in the model.

The Breusch-Pagan Test was used to test heteroscedasticity in the final model. This is a statistical test used to detect heteroscedasticity in a regression model. Applying the Breusch-Pagan Test, the result was $p\text{-value} < 0.000000000000000022$, which means that we do not fail to reject the null hypothesis, indicating that there is significant evidence of heteroscedasticity in the residuals of the regression model. However, in the context of MLM, which is common in longitudinal observations nested within individuals, heteroscedasticity can pose challenges, though this problem is overlooked in the literature.

Extending the discussion: the relationship between Internet, crime and the Covid-19 pandemic

In addition to the findings above, the question remains of how technology can (or cannot) contribute as a criminal opportunity factor, especially in the worldwide context of the Covid-19 pandemic. Undeniably, this setting of abrupt changes in social mobility affected crime occurrence differently (Araújo, 2020); (Bradbury-Jones & Isham, 2020a); (Ribeiro & Silva, 2020). In relation to technology, the Covid-19 pandemic had a big impact on every aspect of our lives, mainly in the virtual domain. With people staying at home and making use of the Internet (the virtual domain of our lives) to do many different activities, virtual crimes have found a great avenue to flourish. This provides fertile ground for new ways to commit crimes, a result of the emergence of many new online users.

Therefore, we expanded the routine activities approach to analyse the post-pandemic changes, in particular, by assuming that the shift in opportunity situations (increased access to the Internet) made it possible for a single criminal action to have the power to reach numerous potential victims in an unpredictable window of time, rather than for offender and victim to physically converge in the absence of guardianship. The hypothesis is that this same technology alters the universe of criminal opportunities, where new criminal modalities find a fertile ground for offenders to act, without the need for convergence in space and time with the victim. Cybercrime is the result of this: the Internet has expanded the explanatory potential of the Routine Activities Theory (Reyns, 2013) by causing victims to be "found" in varied spatial-temporal contexts.

We extended our analysis considering seasonality patterns and forecasting the trend. In this case, we adopted the use of temporal techniques to capture the effect of changing trends over time. Time series analysis helped us understand the underlying causes of trends or systemic patterns over time.

In methodological terms, Holt-Winters (HW) is a very useful and sophisticated model of the exponential smoothing (ETS) class that brings together trend and seasonality conditions, and it is considered an improvement of the ETS models that can assign differentiated weights thereby giving greater importance to the measures. In this regard, α , β and γ represent, respectively, the exponential parameters smoothing: the level/mean, trend and seasonality or each seasonal sub-series (Hyndman et al., 2008).

Thus, we analysed the effects of Internet Access after 2016 and the occurrence of crimes: Cybercrimes, Theft, Theft and Robbery of Vehicles, Violent Crimes, and Property Damage Crimes. Then, we estimated a HW forecast from March 2020, to inspect the pandemic effect on these crimes in Minas Gerais, Brazil. Table 3 below shows the estimated parameters and coefficients.

The results show that cybercrimes significantly increased after the onset of the Covid-19 pandemic as did Internet Access. Violent crimes, Theft and Robbery of Vehicle seem to have significant decreased and the other crimes analysed display similar behaviour before and after the pandemic. This can be observed in Figure 4.

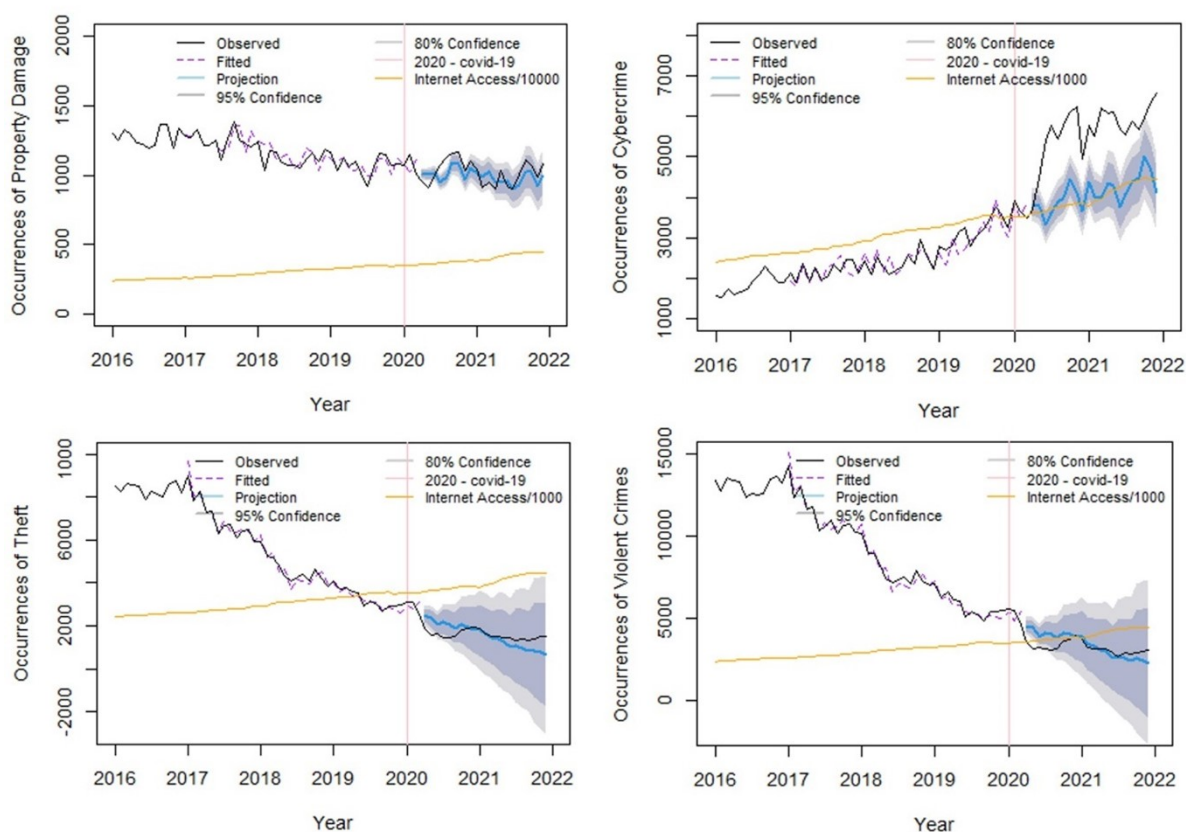
Table 3

Holt-Winters Model Estimated Parameters

Coefficients	Cybercrimes	Theft	Theft and Robbery		
			of Vehicle	Property Damage	Violent Crimes
α	0.309	0.641	0.296	0.203	0.486
β	0.028	0.136	0.260	0.050	0.167
l	0.904	1	0.463	0.1363	0.460
a	3573.667	2580.540	2747.362	1048.220	4775.693
b	40.131	-93.266	-4.898	-4.699	-122.573
RMSE	229.883	239.14	188.864	64.002	375.429

Figure 4

Forecasts from HoltWinters for Occurrences of Property Damage. Cybercrime. Theft and Violent Crimes. 2016 to 2022. Minas Gerais. Brazil



Discussion

Old crimes with a new face

In the field of criminology, cybercrime is an expanding and promising area of study, especially because social networks and the countless possibilities for transactions have allowed people to be connected all over the world more than they ever have before. While crime patterns and trends

may evolve with this revolution, what primarily emerges are new opportunities in new spaces where crimes, previously carried out in physical environments, are now perpetrated in the digital realm, amplifying the opportunities for offenders while making potential victims exponentially more vulnerable. What is more, all this is not limited to a predetermined physical space.

Through the technological revolution of the internet and social media in recent years, the individual is no longer just a receiver, but has become a potential provider of information and data through different means which criminals can take advantage of to commit different types of crimes.

Moreover, law enforcement needs to fully understand the potential for harm that technology can cause. On the other hand, understanding and taking advantage of information technology can be effective in preventing and containing cybercrime. Therefore, prevention and law enforcement must be dynamic and continually adapt to the new ways in which crimes are committed and victims are reached.

Implications

The findings herein have several key implications for theory and research related to cybercrime, but, also, for accurate interpretation of crime trends. The first is to better understand and define the different facets of crime committed on the Internet. It is a challenge to define the types of activities that should be considered crimes in the virtual world, as well as the limitations on the actions of users whose actions are not considered crimes or harmful.

This topic is directly connected to another regarding ways and means of measuring cybercrime. Once a crime has occurred, what forms are used for its propagation? How many individuals are victimized? How many times? And over which period of time? All these issues affect the measurement and underreporting of cybercrime. We may be dealing with crime types whose prevalence in terms of victimization is completely beyond the knowledge of police organizations, either because of the traditional way in which crime is counted, or because of the amount of underreporting, or because of the potential for propagation and reach that a single action can have in the virtual world.

The technology behind the use of smartphones and social media has become easier than ever to keep individuals connected and consume content online. While this may be associated with reduced property damage crime, the increased accessibility and ease of use have also led to concerns about internet addiction and excessive internet use (EIU). EIU can have negative impacts on mental health, including anxiety, Depression, sleep disorders and encompasses multiple domains of adolescent socialization, as can be seen in several studies on this topic ([Alonzo et al. 2021](#); [Blinka et al. 2020](#)).

Likewise, the results allow us to point out that the process of digitalization may be reducing social interactions, especially among young people, and this could be influencing both what happens in the physical space, leading to a consequent reduction in criminal opportunities there, as well as in cyberspace, where there is an increase in the potential convergence between offenders and victims ([Miró-Llinares & Moneva, 2019](#)). Social interactions are the basis of the potential convergence between offenders and victims, and the reduction in time spent in physical space compared to time spent using the internet, related to the new habits of younger generations, could be key to understanding this evolution in crime trends. Additionally, and to understand how this relates to

victimization, it is necessary to better explore the profile of traditional and cybercrime victims, and, in the latter case, considering sociodemographic factors and habits related to internet usage. That is, it is important to understand the factors behind cybercrime victimization and to develop intervention strategies capable of protecting victims and increasing the costs of committing this type of crime.

Lastly, it is crucial to have specialized law enforcement units that are proficient in handling cybercrimes and online threats and to promote prevention and education strategies. By having specialized agents trained in the cybersphere, law enforcement agencies can better identify and track online criminals and their activities, such as: identity theft, fraud and cyberterrorism.

Future Avenues of research

This study contributes to the field of criminology by demonstrating how the convergence between technology, Internet access and criminal behaviour has reshaped the landscape of crime, with notable growth in cybercrimes following the digitalization process and increased connectivity. In particular, it fills a gap regarding longitudinal studies on cybercrime and the effects of technology among the juvenile population as an important socializing factor and new style of everyday life.

One clear effect of changes in socializing and lifestyle is the potential for cyberbullying, which is a serious issue that can have detrimental effects on a person's mental health and well-being. While males and females may bully in different ways, it is important to recognize that both genders can engage in cyberbullying behaviours. Parallel to the changes in the form of social interactions that the technological revolution is promoting, the anonymity and perceived distance of the online environment can make it easier for individuals of any gender to engage in bullying behaviour and possible becoming involved in crimes of other natures as both perpetrators and potential victims through a process of victim-offender overlap.

Secondly, if there is evidence of enormous criminogenic potential in the virtual world, where the dark web constitutes a particularly high level, even more complex and unimaginable. While the dark web can be used for legal purposes such as protecting users' privacy and freedom of speech, it is also notorious for being a haven for illegal activities. These activities can include hacking websites or stealing personal information, which can be used for identity theft or fraud and many other types of crimes.

Thirdly, it is important to recognize that conventional prevention tactics adopted by law enforcement agencies do not work well in cyberspace (Ngo & Jaishankar. 2017). Law enforcement agencies should enhance collaboration between agencies within their country and other countries to combat the offenses that occur in this field. In terms of security, it is important to reflect upon how to balance humans and machines in a new world, and incorporate all possibilities provided by technology securely and safely.

Finally, we believe that the future and promising trajectory of research on cybercrime must focus on greater collaboration across disciplines, methodological advancements, greater understanding of behavioural aspects, and increased emphasis on victim experiences in online spaces.

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APPENDIX

Table 4

Final Model Variance Inflation Factors (VIFs)

Time	1.090496	Access_tx	2.35059
Sex	1.257384	Teenager (<17 y)	1.53638
Youth (18-29 y)	1.457454	Race	1.239412
Population 20-50 K	1.063023	Population 50-150 K	1.051098
Population 150-500 K	1.035204	Population +500 K	1.023504
Time:Access_tx:Youth (18-29 y)	1.636522	Time:Access_tx:Teenager (<17 y)	1.478036
Time:Access_tx:Race	1.513083	Time:Access_tx:Sex	2.541417
Time:Access_tx:Population 20-50 K	1.422738	Time:Access_tx:Population 50-150 K	1.581347
Time:Access_tx:Population 150-500 K	1.204702	Time:Access_tx:Population +500 K	1.160953
Mean (VIF) = 1.42463			

Figure 5

Final Model Random Effects Plots

