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ARTICLE

A quantile panel examination of the moderation effects of guardianship on residential burglary

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Abstract
Do informal and formal mechanisms of guardianship work together to reduce residential burglary? In this article we argue that informal guardianship moderates the relationship between formal mechanisms of guardianship and residential burglary. Formal guardianship requires some level of social cohesion and trust to be effective against residential burglary. We test this argument with the use of robust panel quantile methods controlling for time effects, spatial effects, and alternative explanations. Using Mexico City neighborhood crime and census data, we show evidence of a moderating weakening effect of informal guardianship on the previous relationship, particularly in deprived neighborhoods and only in the upper quantiles of the residential burglary distribution. In addition, the moderation effects seem to have weakened over time. In sum, the combination of guardianship mechanisms seems to have been more effective in high burglary risk deprived neighborhoods, although their combination seems to have become less relevant.

Keywords Guardianship · Residential burglary · Quantile panel regression · Mexico

1 Introduction

Burglars have particular concern regarding informal guardianship (Bennett & Wright, 1984; Reynald, 2018; van Sintemaartensdijk et al., 2022). Many studies have examined whether informal guardianship or informal social controls have main effects on residential burglary (Chen et al., 2017; Reynald, 2009, 2010; Tseloni et al., 2004; Vilalta & Fondevila, 2021; Wickes et al., 2017; Wilcox et al., 2007; Yue et al., 2022; Zhang et al., 2007).

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Evidence is mixed in this regard. Other few studies have analyzed whether formal mechanisms of guardianship or those provided by law enforcement such as traditional policing or community policing have a main effect of residential burglary (Armstrong, 2017; Noh, 2019; Yue & Zhu, 2019). Evidence is also mixed in this regard. However, whether the two interact with each other to affect residential burglary has not been examined in the scholarly literature.

One clue on the possibility of an interaction effect between informal and formal guardianships can be found in a study that reports that the early detection and reporting of the burglar strongly affects the success of police response (Coupe & Blake, 2011). This piece of evidence suggests that formal guardianship effectiveness partially depends on informal guardianship. Logic dictates that police can only respond to suspicious behavior or to crime either by direct detection or by someone else´s detection and report. Under this logic, in this study we test whether informal guardianship moderates the relationship between formal guardianship and residential burglary. More in detail, we test whether concentrated disadvantage, as a proxy for informal social control (a key element of collective efficacy) moderates the relationship between two specific mechanisms of formal guardianship, namely, police-monitored CCTV density and police micro-station density, with residential burglary. We do so by using recent data from Mexico City neighborhoods and based on Routine activity and Collective Efficacy theories premises.

When testing the moderation effect of informal guardianship on the relationship between formal guardianship with residential burglary, we must take into account the methodological implications of the data, the selection of variables, and the functional forms of the relationships being tested. For instance, cross-sectional specifications impose restrictive assumptions and limitations, among them, endogeneity bias from different sources such as measurement error, omitted variable bias, and/or simultaneity bias (Vilalta et al., 2022). Furthermore, we do not know whether main and interaction effects are constant throughout the residential burglary distribution –we have neither theoretical nor empirical grounds for this assumption. In this respect, our quantile panel modelling approach allowed us to uncover relationships that are significant only in some parts of the conditional distribution. Furthermore, this modelling approach is robust to non-normal distribution of error terms and estimates are less sensitive to outliers (Rennó Santos et al., 2018; Vilalta et al., 2021a) –outliers are often found with the use of geographically aggregated data. In sum, it may be that previous mixed evidence may be due to methodological rather than *ad-hoc* contextual adjustments of theories. The empirical strategy in this study is designed to minimize the effects of methodological limitations as much as possible.

The study proceeds as follows. We first review the evidence on the relationship between informal and formal mechanisms of guardianship with residential burglary and formulate our theoretical argument (Sect. 1). We then formulate our hypotheses (Sect. 2). After presenting the data, measures and methods used in this study (Sect. 3), we present our results of our data analyses (Sect. 4). Finally, we discuss the results in detail and conclude with explanations and interpretations for our findings (Sect. 5).

2 Evidence and theoretical argument

2.1 Residential burglary and guardianship

In its original formulation, crime opportunity theories distinguish between three types of crime risk factors, namely, motivational factors, social factors, and situational factors, where the latter refer to any feature in the immediate environment which may provide sufficient stimulus conditions for criminal behavior (Mayhew et al., 1976). Routine Activity theory, as a crime opportunity theory, builds upon these factors to postulate that most criminal acts need (1) motivated offenders and (2) suitable targets to converge in space and time in (3) the absence of capable guardians (Cohen & Felson, 1979, 2016; Spano & Freilich, 2009).[1] A motivated offender is anyone who has an inclination to commit a crime, whereas target suitability is a complex concept that integrates monetary value, physical visibility, accessibility, and resistance to victimization (Vilalta & Fondevila, 2021). Finally, guardianship is a concept that has been understood over time in wide terms such as "… any spatiotemporally specific supervision of people or property by other people which may prevent criminal violations from occurring", or "… the physical or symbolic presence of an individual (or group of individuals) that acts (either intentionally or unintentionally) to deter a potential criminal event" (Hollis-Peel et al., 2011). What is clear, we believe, is that "at the heart of the concept of guardianship is the mechanism of supervision, which inherently implies regulation and control through surveillance" as well as "one cannot understand guardianship as a process without attention to guardians as agents" (Hollis et al., 2013, p. 67).

In this respect, studies have further developed the concept of guardianship to distinguish between four different mechanisms, namely, physical (i.e., target hardening), personal (i.e., home occupancy), natural (i.e., surveillance through environmental design), and social (i.e., informal control) (Wilcox et al., 2007). Other authors distinguish between formal and informal types or mechanisms of guardianship, where the former refers to guardians acting in some official capacity (e.g., police and security personnel) and the latter refers to any "… informal process through which citizens protect or defend targets against victimization" (Reynald, 2019, p. 16) and which may be provided either by neighborhood residents and passersby (van Sintemaartensdijk et al., 2022). In this last regard, attitudes, perceptions and relationships with neighbors is crucial for informal guardianship to function (Reynald & Moir, 2019). In this sense, anyone going about his/her own routine may provide some degree of security and this may be considered a Guardian (Felson & Boba, 2010; Hollis-Peel et al., 2011).

Briefly put, formal guardianship refers to any prescribed on-purpose crime control mechanisms such as traditional policing or community policing (Sampson et al., 1998), and informal guardianship refers unofficial crime control mechanisms such as taking note of strangers, calling the police, neighbor-provided surveillance including digital neighborhood watch and community safety apps etc.

[1] RA theory is considered a macro-level theory as it proposes that these three situational factors are shaped by trends and fluctuations in social structure, such as changes in technology and community organization (Cohen & Felson, 2016). It follows that crime opportunities against delivery drivers may increase if changes in social structure cause an increase in home delivery services, which is what we saw during the COVID-19 pandemic.

In this last regard, it is important to note that guardianship, formal or informal, may not only be physical but also symbolic, meaning that guardianship can operate through the illusion or suggestion, factual or not, of being watched. Therefore, another distinction are formal symbolic guardianship mechanisms (e.g., police signs) and informal symbolic guardianship mechanisms (e.g., neighborhood watch signs) (van Sintemaartensdijk et al., 2022).

Common mechanisms of formal guardianship in Mexico City are police micro-stations and police-monitored CCTV systems, where the former can be classified as a formal physical mechanism of guardianship, and the latter as a formal symbolic mechanism. Police-monitored CCTV systems are becoming increasingly popular in Mexico City. Since 2007, the Mexico City police has been installing CCTV systems in public places such as government buildings, parks, banking and commercial areas, roads, highway exits, metro stations, and other places with large numbers of people and traffic. Large-scale use of CCTV by Mexico City police began in 2006 when the newly elected Governor of the city then promised that a massive high-tech video surveillance system would be installed during his administration. Accordingly, the high-tech public security *Mi-Ciudad-Segura* program started in 2009. This program is basically a massive CCTV security surveillance network integrated with other high-tech communication features enhancing police tracking capabilities, traffic control, and emergency call handling and dispatching. Police-monitored CCTV systems are a purposeful extension of the surveillance capacity of the police (Fondevila et al., 2021).

More recently, between 2019 and 2022, 13,243 new CCTV systems were installed as part of a new policing strategy called *Mi-Calle*. According to the Mexico City police website,[2] these new systems are additional to other 35,511 already installed throughout the city. In this study we know in what neighborhoods are the *Mi-Calle* CCTV systems located, however the geographical location of the other 35 thousand CCTV systems is unknown to us.

It is important to know that police-monitored CCTV systems can be activated by citizens themselves in case of an emergency. These CCTV systems incorporate a panic button that can be used by neighborhood residents or any passerby to alert the police of the occurrence of a crime. The CCTV system is activated when the resident or passerby reaches the police call center and the CCTV operator visually follows the emergency and dispatches the police officers to the location of the alert.

With regards to police micro-stations, they are used for police surveillance and to facilitate the implementation of community policing (i.e., *policia de barrio*). These are small two-floor buildings located on high car-traffic or high pedestrian-traffic areas. They also serve as meeting place and resting locations for car, bicycle, and walking police patrol officers. There was a total of 496 micro-stations distributed across 429 neighborhoods in 2022. Residents can also these locations to alert the police of a crime.

The use of these formal mechanisms, police-monitored CCTV systems and police micro-stations, is based on rational choice theory. It is expected that offenders will be less likely to commit a crime if they know they are being watched and have a greater risk of being apprehended (La Vigne et al., 2011). By extension, it is expected that neighborhoods with higher densities of police-monitored CCTV systems and police micro-stations will be less attractive for residential burglary as chances for arrest are higher. However, previous studies show mixed results with regards to the impact that police-monitored CCTV may

[2] Visit: https://www.c5.cdmx.gob.mx/.

have on residential burglary, with one study reporting a negative independent correlation in Wuhan, China (Yue & Zhu, 2019) and another reporting no significant independent correlation with residential burglary in Seoul, South Korea (Noh, 2019). The only study we found examining whether distance to police stations correlates with residential burglary shows no significant correlation (Noh, 2019). However, one recent study on the deterrent effect of police stations on homicide, robbery and theft crimes in Buenos Aires show evidence of a geographic pattern of these crimes increasing in frequency around police stations until a certain distance when they begin to decrease once again, thus suggesting that distance to police stations impacts offenders´ rational choices (Fondevila et al., 2021). It must be considered that police stations are important not only for their symbolic potential deterrence effect but because their locations affects their response time to a crime location (Noh, 2019).

One study argues by analogy to murder and rape, that CCTV systems do not deter burglars "since many burglaries could occur out of a camera´s view" (p. 264, Caplan et al., 2011). We disagree. We would argue that police-monitored CCTV systems may have a deterrence effect on residential burglary because of their symbolic nature, that is, their capacity to signal to the potential burglar that the police may be monitoring him or her. Naturally, for police-monitored CCTV systems to work, they have to be well adapted into the police function (La Vigne et al., 2011; Piza et al., 2014a), and arrest and punishment have to be certain (Piza et al., 2014b).

With regards to informal guardianship, that is, any type of guardianship that requires citizen involvement or at the least the informal cooperation of neighbors (Norris & Kaniasty, 1992; Reynald, 2019), one very common strategy in Mexico City is the closing of streets to reduce or restrict vehicle and pedestrian traffic, with the use of fences, locked gates, traffic barriers, and security booths with or without private guards (Vilalta, 2012). These closings require the previous agreement of residents of the street and a formal request to the local authorities. As such, informal guardianship requires some level of collective efficacy. This reinforces the premise that guardianship does not have to be intentional (Felson, 1995). We touch upon the link between informal guardianship and collective efficacy theory and informal in more detail in the next section.

2.2 Informal guardianship, collective efficacy and concentrated disadvantage

The argument that collective efficacy fosters informal guardianship against residential burglary is neither new nor ours (Schaefer & Mazerolle, 2017; Wilcox et al., 2007; Zhang et al., 2007). However, previous studies have analyzed the role of informal social controls or informal guardianship as having main effects on residential burglary, rather than examining whether informal guardianship moderates the relationship between formal guardianship mechanisms and residential burglary.

Collective efficacy (CE) is a measurable construct at the neighborhood level that represents social cohesion combined with willingness to intervene for the common good (Sampson et al., 1997). The main argument of CE theory is twofold. First, that it reduces crime by fostering informal social control, that is, the willingness to control group behaviors and prevent neighborhood disorder and violence. Second, that the relationship between neighborhood social composition and crime is substantially mediated by CE (see Fig. 1). This theory is strongly based on theoretical explanations of social control, social disorganization, and the social sources of delinquency (Kornhauser, 1978; Sampson & Groves, 1989; Shaw & McKay, 1942).

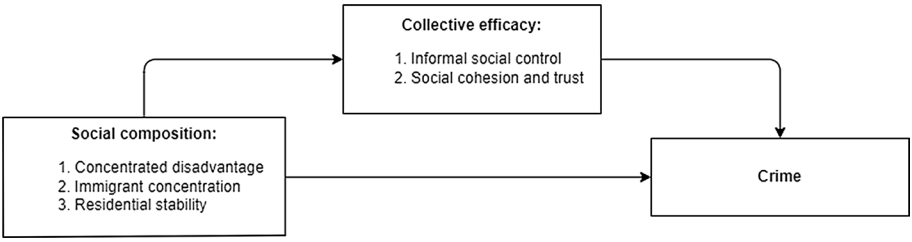


Fig. 1 Collective efficacy theory *Source*: Sampson et al. (1997)

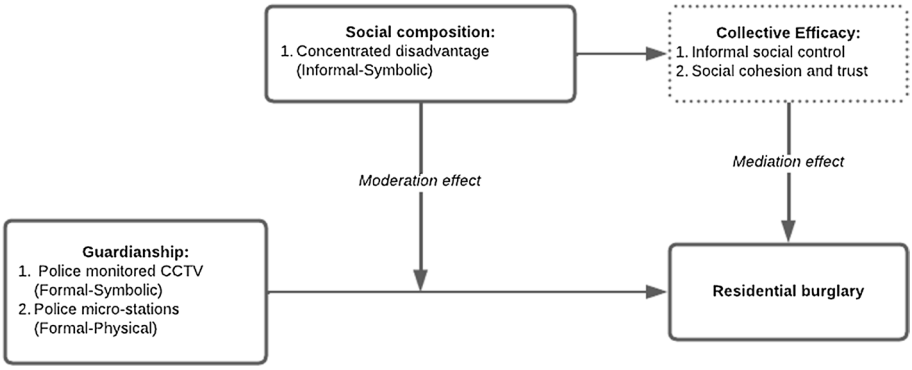


Fig. 2 The moderating role of concentrated disadvantage in the relationship between residential burglary and formal measures of guardianship. *Source* Own elaboration. In parentheses the type of guardianship. The dashed outline refers to unobserved mechanisms

To assess neighborhood differences in social composition, Sampson et al. (1997) conducted a factor analysis of ten census variables which resulted in three dimensions, namely, concentrated disadvantage (as a dimension of urban poverty), residential stability, and immigrant concentration.[3] On the other hand, CE, that is, the combination of informal social control and social cohesion and trust, was measured based on ten opinion-based questions in a neighborhood representative survey, regarding their neighbors´ willingness to intervene to prevent antisocial behaviors in their neighborhood of residence as well as what were the levels of trust among them. These Likert scale responses were aggregated at the neighborhood level, and given the strong correlation between them, measures were combined into a summary measure they labeled "collective efficacy". Sampson et al. (1997) found that their summary measure of CE mediated the correlations between concentrated disadvantage and residential stability with violent victimization and perceived neighborhood violence. Results with regards to the immigrant concentration indicator were mixed (Fig. 2).

Given the scarcity of social process-based measures at the neighborhood level, and given that Sampson et al. (1997) census-based social composition measures were strongly

[3] Concentrated disadvantage as concept was originally coined by the English Schools Council in 1970 to characterize inner-city school districts suffering from cultural deprivation and thus educational disadvantage (Schools Council, 1970).

correlated to (and mediated by) their survey-based CE measures and outcome measures of victimization and perceived victimization, a variety of structural composition measures have been used extensively since then as proxy indicators of neighborhood CE processes. The premise has been that neighborhood variations in census-based social composition measures are able to represent neighborhood variations in informal social controls and social cohesion and trust (Vilalta et al., 2021b).

2.3 Theoretical argument

In a similar way that Sampson et al. (1997) argued that collective efficacy (CE) does not exist in a social vacuum and that the relationship between neighborhood social composition and crime is substantially mediated by CE, we argue that formal mechanisms of guardianship benefits from informal mechanisms of guardianship, and thus that the relationship between formal guardianship and residential burglary is moderated by levels of CE. More in detail, we argue that a substantial portion of the relationship between formal guardianship and residential burglary can be attributed to neighborhood differences in CE as proxied by concentrated disadvantage (CD).

One reason why we argue that CD moderates the relationship between formal guardianship and residential burglary is that CD serves as a proxy measure of weak social cohesion and community attachment. We can expect less cohesion and community attachment in neighborhoods with high levels of CD as residents are less interested in local issues and more interested in leaving their neighborhood (Andersen, 2008; Bursik Jr, 1988; Kornhauser, 1978; Shaw & McKay, 1942). It must be noted that CD is not a cause of crime as it does not affect it directly. Rather, are the weak structures of informal control in deprived neighborhoods that decrease the costs of crime (Bursik Jr, 1988). This is why residents in economically disadvantaged neighborhoods are thought to be less likely to report deviant behaviors and to intervene in public disorders as they are less committed to their neighborhood –not because they are poor (Bursik Jr, 1988; Sampson, 1987; Sampson & Wilson, 2020).

The second reason why we argue that CD affects formal guardianship effectiveness, is that residents and passersby in disadvantaged neighborhoods may be less inclined to use formal mechanisms of guardianship such as police-monitored CCTV systems or police micro-stations as they may feel more vulnerable to retaliation and revenge from offenders. We find two pieces of indirect evidence of this in the Mexican national victimization survey, which shows, first, that about 23% of victims of crime who knew their aggressor either "by sight" or "by little acquaintance" did not report their victimization to the police due to fear of the aggressor, and two, that victims who did not trust their neighbors were also less likely to report their victimization to the police (Inegi, 2021). Evidence in previous studies is also supportive of the previous line of reasoning, namely, that in the context of economic disadvantage, informal social controls are too weak to control crime and deviant behaviors (Benson et al., 2004; Chamberlain & Hipp, 2015; Hipp & Wickes, 2017; Mazerolle et al., 2010; Sampson & Wilson, 2020; Vilalta et al., 2021a, 2021b).

The third and final reason why we argue that CD moderates the relationship between formal guardianship and residential burglary, is that formal mechanisms require some participation of the neighborhood residents to work. As police can only respond to suspicious behavior or to crime either by seeing it directly or by someone else reporting it, some level of willingness to use formal mechanisms is necessary in order to deter burglars.

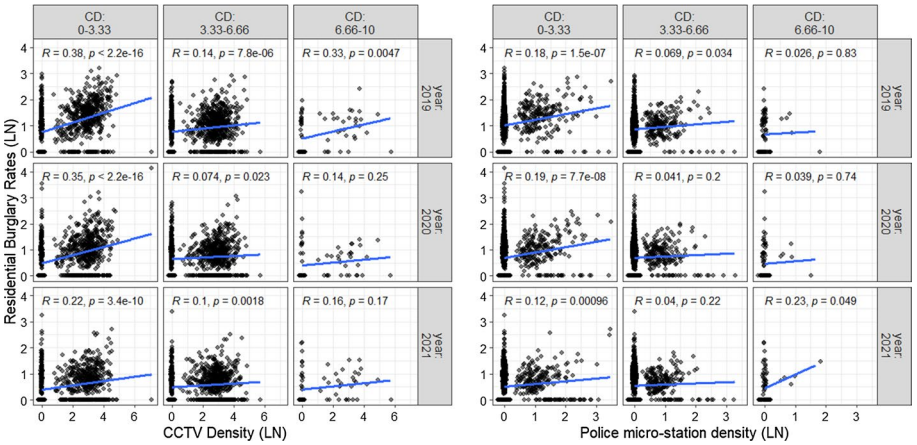


Fig. 3 Correlation plots w/ Pearson correlation coefficients paneled by equal levels of concentrated disadvantage (CD) and by year, 2019–2021. Lower values represent lower levels of concentrated disadvantage (CD was rescaled 0 to 10)

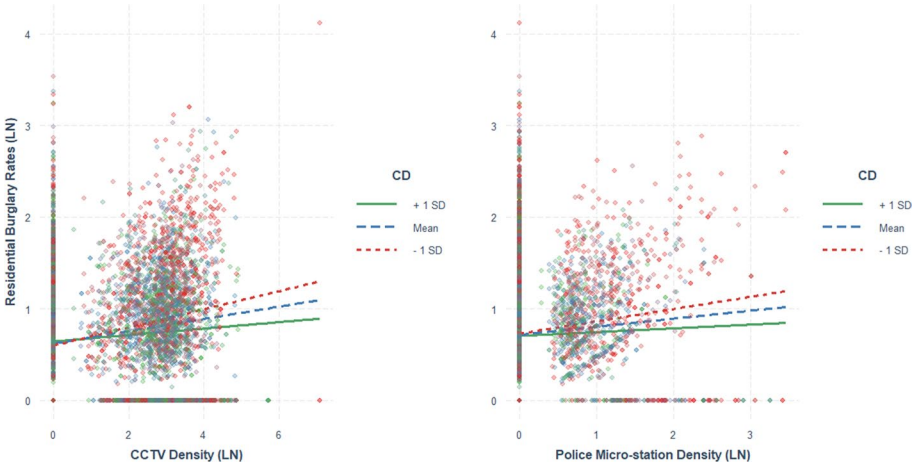


Fig. 4 Interaction plots by standard deviation levels of concentrated disadvantage (CD), 2019–2021

Hypotheses In this article, we argue that informal guardianship interacts with formal social guardianship mechanisms to make the latter more effective against residential burglary. More in detail, we hypothesize that CD as a proxy measure of informal guardianship and operating through collective efficacy (CE), moderates the relationship between CCTV density (formal symbolic) and police micro-stations density (formal physical) as formal mechanisms of guardianship with residential burglary.

A quick look at the correlation plots (see Fig. 3) and the interaction plots (Fig. 4) below, suggest the presence of a moderation effect of CD on the relationship between our two measures of formal guardianship and residential burglary. Figures 3 and 4 show that

neither the slopes nor correlation coefficients seem parallel or are statistically significant across all levels of CD or across time. Likewise, we have no reason to assume moderation effects are linear throughout the entire distribution of residential burglary. Consequently, we also hypothesize that moderation effects of CD will not be the same across the distribution of residential burglary.

We summarize these assertions in two hypotheses that serve as the leading threads in our empirical analysis:

H1 Concentrated disadvantage (CD) moderates the relationship between police-monitored CCTV density and police micro-stations density with residential burglary, creating a sort of synergistic beneficial interaction.

Given that our measure of CD varies from zero to ten where zero (0) indicates minimum concentrated disadvantage and ten (10) maximum concentrated disadvantage, the direction of the moderation effect (i.e., the sign of the interaction term in the regression equation) must be negative for this hypothesis to be not rejected. A negative sign in the interaction term would indicate that neighborhoods the strength of the correlation between police-monitored CCTV density and residential burglary is higher (more beneficial) in neighborhoods with higher collective efficacy levels as proxied by low levels of concentrated disadvantage.

H2 Moderation effects are not linear across the distribution of neighborhood residential burglary rates.

For H2 to not be rejected, regression coefficients must differ significantly by quantile and from the conventional mean effect.

To explain these conditions more in detail, we now turn to the data, measures and methods of this study (Table 1).

3 Data, measures and methods

3.1 Dependent variable

Residential burglary rates were calculated dividing the count of residential burglaries recorded in criminal investigations by the number of private housing units multiplied by 1000. Residential burglary data were obtained from the local Office of the Attorney of Mexico City. These data can be downloaded from the Open Data office of Mexico City.[4] These data contain the geographic coordinate of the residential burglary crime incident (point data). Burglary incidents were aggregated to their corresponding neighborhood (polygon data). The number of housing units at the city block level was obtained from the 2020 Census and they were also aggregated at the neighborhood level. Table 2 presents the descriptive statistics of neighborhood residential burglary rates per quantile. In 2021, the number of neighborhoods per quantile is not symmetric as more than a third of neighborhoods reported a zero rate in residential burglaries.

[4] Visit: https://datos.cdmx.gob.mx/pages/home/.

Table 1 Types of guardianship as authors define it and their correlation with residential burglary

Study	Measure	Type of guardianship	Independent correlation
van Sintemaartensdijk (2022)	Neigh. watch signs	Symbolic formal	Both affect burglar choices
	Police signs	Symbolic informal	
Yue et al. (2022)	Unemployment	Natural	(−)
Vilalta and Fondevila (2021)	Live alone	Personal	(n.s.)
	Salary worker	Personal	(−)
	Length of residence	Social	(n.s.)
	Quarrels among neigh	Social	(n.s.)
	Gangs in the neigh	Social	(+)
	Alcohol use in the neigh	Social	(n.s.)
	Drug use in the neigh	Social	(n.s.)
	Public lighting	Natural	(−)
Yue and Zhu (2019)	CCTV	Social	(−)
	Policing room density	Social	(n.s.)
Armstrong (2017)	Traditional policing Community/Prob. Or. Pol	Formal	(n.s.)
	COMPSTAT policing Intelligence-Led policing Evidence based policing	Formal	(n.s.)
		Formal	(n.s.)
	Hot-spot based policing	Formal	(n.s.)
		Formal	(n.s.)
		Formal	(n.s.)
Chen et al. (2017)	Pop. < 6 or > 60 yrs. Old	Social	(n.s.)
Wickes et al. (2017)	Guardianship availability	Social	(−)
	Guardianship expectations	Social	(−)
	Guardianship action	Social	(n.s.)
Kuo (2015)	Number of adults in HH	Social	(n.s.)
	Length of residence	Social	(n.s.)
	HH ownership	Social	(−)
	Security items (7)	Physical	(Varied)
Breetzke et al. (2013)	Population density	Social	(+)
	Road density	Physical	(n.s.)
	Gated neighborhood	Social/Physical	(+)
Johnson and Bowers, (2010)	Street permeability	Physical	(+)

Table 1 (continued)

Study	Measure	Type of guardianship	Independent correlation
Reynald (2009, 2010)	Guardianship intensity	Social	(−)
Zhang et al. (2007)	Somebody often home	Personal	(−)
	Length of residence	Social	(−)
	Neighbors watch	Social	(n.s.)
	Locking doors when away	Physical	(n.s.)
	Anti-theft door	Physical	(n.s.)
Wilcox et. al. (2007)	Safety precautions	Physical	(−)
	Home occupancy	Personal	(−)
	Neighbors watch	Social	(n.s.)
	Defensible characteristics	Natural	(−)
Tseloni et al., (2004)*	Number of adults in HH	Social	(−)
	Children < 16 yrs. old	Social	(+)
	Lone parent HH	Social	(+)
	Unemployed status	Social	(+)
	Divorced status	Social	(+)
	Hours HH is empty	Social	(+)
	Number of evenings out	Social	(n.s.)
	Time spent shopping	Social	(n.s.)
	Neighbors watch dwelling	Social	(+)
	Neighborh. watch program	Physical	(+)
	Security measures (5)	Physical	(Varied)

Own elaboration. *Correlation is reported if significant in at least onecountry

Table 2 Descriptive statistics by Residential Burglary Quantile and Year

		Obs	Mean	Std. Dev	CV	Min	Max
Residential burglary rates:							
2019	q25	608	0.193	0.337	1.743	0	0.992
	q50	608	1.812	0.471	0.26	0.999	2.706
	q75	608	5.15	2.871	0.557	2.714	23.529
2020	q25	608	0.002	0.024	11.076	0	0.287
	q50	608	1.074	0.383	0.356	0.299	1.737
	q75	608	3.829	3.865	1.009	1.74	60.606
2021	q25	733	0.000	0.000	0.000	0.000	0.000
	q50	484	0.759	0.269	0.354	0.155	1.225
	q75	607	2.616	2.182	0.834	1.226	28.169
Police-monitored CCTV density:							
2019	q25	608	12.856	53.947	4.196	0.000	1,200.0
	q50	608	13.283	15.537	1.170	0.000	123.2
	q75	608	18.991	21.541	1.134	0.000	135.9
2020	q25	608	11.356	25.193	2.218	0.000	309.2
	q50	608	13.371	14.384	1.076	0.000	98.3
	q75	608	20.402	52.464	2.571	0.000	1,200.0
2021	q25	733	14.256	50.473	3.541	0.000	1,200.0
	q50	484	14.925	16.619	1.113	0.000	135.9
	q75	607	16.088	18.601	1.156	0.000	129.4
Police micro-station density:							
2019	q25	608	0.496	2.253	4.542	0.000	29.2
	q50	608	0.485	1.029	2.124	0.000	8.2
	q75	608	0.963	2.521	2.619	0.000	30.6
2020	q25	608	0.530	2.402	4.533	0.000	29.2
	q50	608	0.528	0.971	1.837	0.000	6.5
	q75	608	0.885	2.418	2.731	0.000	30.6
2021	q25	733	0.612	2.330	3.806	0.000	24.9
	q50	484	0.551	0.859	1.558	0.000	7.0
	q75	607	0.768	2.345	3.052	0.000	30.6
Concentrated disadvantage (rescaled 0–10):							
2019	q25	608	3.901	1.684	0.432	0.056	10.0
	q50	608	3.884	1.461	0.376	0.000	8.2
	q75	608	3.207	1.485	0.463	0.316	8.6
2020	q25	608	3.701	1.753	0.474	0.000	10.0
	q50	608	3.811	1.455	0.382	0.222	8.2
	q75	608	3.480	1.498	0.431	0.316	8.6
2021	q25	733	3.580	1.654	0.462	0.000	10.0
	q50	484	3.835	1.494	0.390	0.222	8.2
	q75	607	3.629	1.545	0.426	0.316	9.6

The decreasing trend in residential burglary rates between 2019 and 2021 varies by quantile (see Fig. 4), where the greatest reduction can be observed in the highest quantile. This figure presents the DV transformed in natural logarithms (Ln) for clarity. Regression

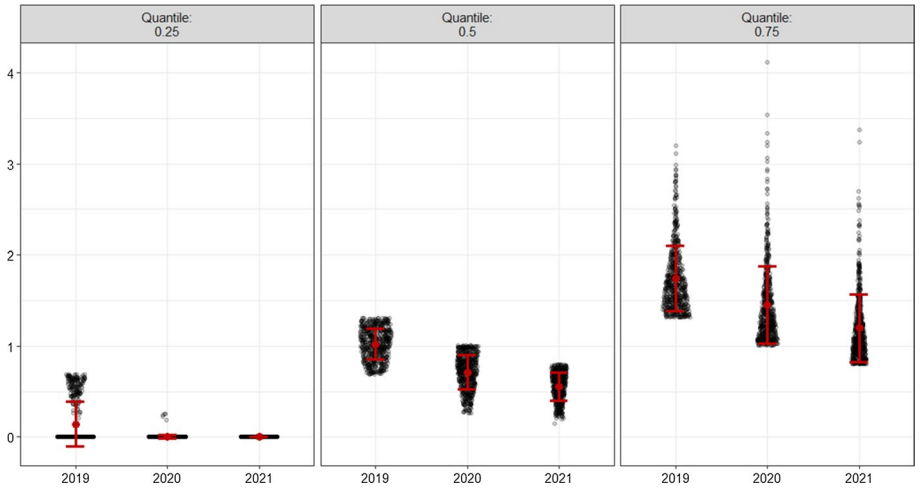


Fig. 5 Residential burglary rates (Ln) by quantile and year, 2019–2021. The whiskers represent one standard deviation to the yearly mean

analyses later will use this transformation in the DV. It is also noticeable that the coefficient of variation is most of the time larger in the 75th quantile, indicating greater variability in the distribution of burglary rates, suggesting that a regression-to-the mean approach may not provide the best estimates of the correlations between variables.

Neighborhood residential burglary rates (LN) were also spatially autocorrelated to its contiguous neighbors (I = 0.252, $p = 0.001$). The map below of Mexico City neighborhoods (see Fig. 5) shows the quantile distribution of the burglary rates (LN) for the entire period. It can be seen that burglary rates were more prevalent in neighborhoods located in the west and southwest of the city. However, the Moran´s I coefficients for each year indicate that the neighborhood geography of residential burglary became less marked very quickly between 2019 and 2021 (I = 0.290, I = 0.188, and I = 0.138, respectively),[5] thus less spatially predictable.

3.2 Independent variables

Formal guardianship was represented with two measures, namely, CCTV density and Police micro-station density. CCTV density is measured as the number of police CCTV systems installed in each neighborhood between November of 2019 and February of 2022 divided by the neighborhood residents × 10,000. A total of 13,243 CCTV systems were installed in that period. These data can be also downloaded from the Open Data office of Mexico City.[6] These data contain the geographic coordinate of the neighborhood where these systems are located. Police micro-station density was measured as the number of micro-stations divided by neighborhood residents × 10,000. There were 496 police micro-stations in the period of study.

[5] These coefficients are all statistically significant at the 0.01 level.

[6] Visit: https://datos.cdmx.gob.mx/dataset/programa-mi-calle-shapes.

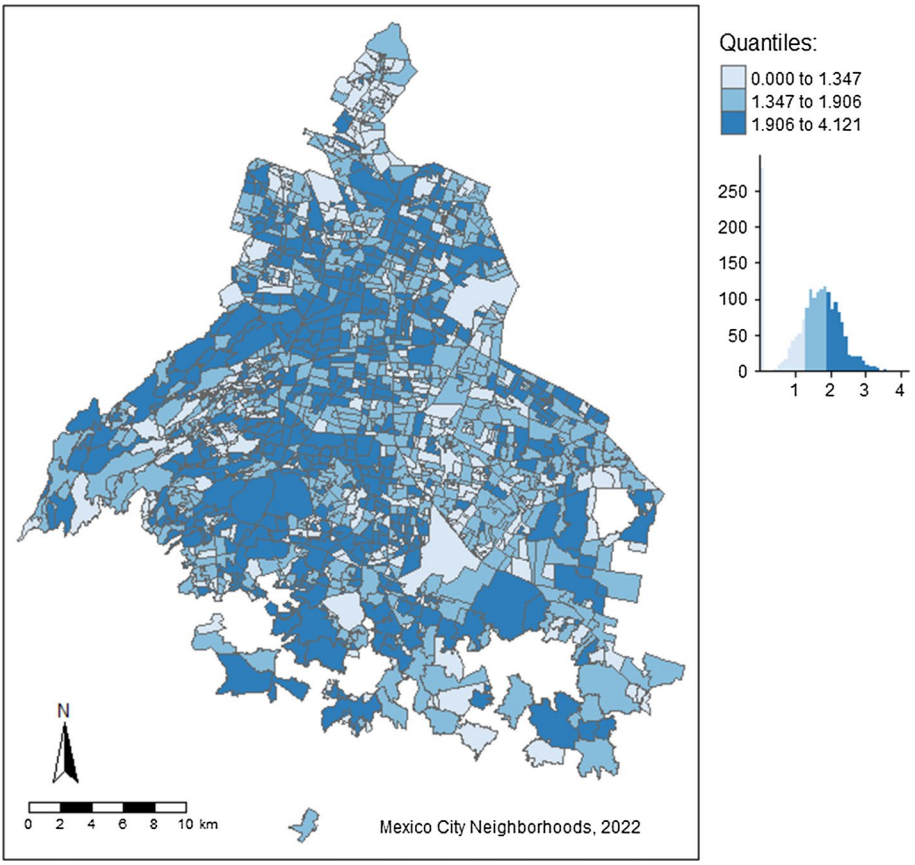


Fig. 6 Map of Residential Burglary Rates by Quantile 25th, 50th and 75th, 2019–2021. Burglary rates per 1000 private occupied housing units

Table 3 Pearson correlation coefficients between yearly measures of the DV and IVs, 2019–2021

	Residential Burglary Rates
CCTV density (2019)	0.267***
CCTV density (2020)	0.217***
CCTV density (2021)	0.162***
Police micro-station density (2019)	0.154***
Police micro-station density (2020)	0.134***
Police micro-station density (2021)	0.085***
Concentrated disadvantage (CD) (2019)	−0.174***
Concentrated disadvantage (CD) (2020)	−0.077***
Concentrated disadvantage (CD) (2021)	−0.001

All variables transformed to Ln with the exception of CD which was rescaled to 0–10 for clarity of interpretation

***$p < 0.01$, **$p < 0.05$

We conducted a Principal Component Analysis (PCA) to construct an index measure of neighborhood CD. This index measure was constructed based on the percent of population without medical health services, the percent of population 15 years or older without schooling, and the percent of households without computer and internet access. We selected these variables as, in our view, health, education, and digital divide measures are appropriate indicators of contemporary economic deprivation. In particular, internet access is reported to support social engagement (Hampton, 2010), where social engagement happens to be a necessary condition for trust, social cohesion, and eventually CE to occur. The first component of our PCA index explains 73.7% of the total variation (see Table 7 in the appendix) and is negatively and significantly correlated with neighborhood residential burglary rates. The scattergrams below (see Fig. 6) show the independent relationship between the independent variable (VI) measures and the dependent variable (DV). Table 3 shows the correlations of each IV with the DV.

3.3 Empirical strategy

As we said in the introduction, we have no grounds to sustain that main and interaction effects are constant throughout the residential burglary distribution. To test whether relationships are constant or not throughout the DV distribution, we use a quantile panel modelling approach that is designed to test whether relationships are significant only in some parts of the conditional distribution. This modelling approach is also robust to non-normal distribution of error terms, and estimates are less sensitive to outliers (Rennó Santos et al., 2018; Vilalta et al., 2021a).

Given the panel structure of our data, we make use of a panel quantile regression approach. Conventional panel data regression analysis allows to control for time-invariant unobserved heterogeneity, while panel quantile regression adds to the latter the capacity to estimate heterogeneous effects at different points of the quantile distribution of the dependent variable (Abrevaya, 2002).

Consider the classical linear random effects model (Koenker, 2004):

$$y_{ij} = x_{ij}\beta + \alpha_i + u_{ij} j = 1, \ldots, m_i, i = 1, \ldots, n. \tag{1}$$

where the subscript "i" indexes the neighborhood and the subscript "j" index the "m" distinct measures over time made on the neighborhood.

The main problem in this specification is unobserved heterogeneity. To address this issue, Koenker´s panel quantile regression approach introduces a penalty term to eliminate unobserved fixed effects (Yan et al., 2019). By shrinking the unconstrained estimated values of alpha toward a common value, the individual fixed-effect estimates are improved (Koenker, 2004).

Thus, the estimation of the panel conditional quantile functions (tau) of the dependent variable would have the following form (Koenker, 2004):

$$Q_{y_{ij}}\left(\tau | x_{ij}\right) = \alpha_i + x_{ij}^T \beta_{(\tau)} j = 1, \ldots, m_i, i = 1, \ldots, n. \tag{2}$$

In order to estimate the previous model for several quantiles simultaneously, Koenker (2004) proposes the following minimization (Yan et al., 2019):

$$argmin_{(\alpha)} \sum_{k=1}^{q} \sum_{j=1}^{n} \sum_{i=1}^{m_i} w_k \rho_{\tau_k}\left(y_{ij} - \alpha_i - \beta_{(i)}\right) + \mu \sum_{I=1}^{N} |\beta_i| \tag{3}$$

$$\rho_\tau(y) = y\left(\tau - 1_{y<0}\right) \tag{4}$$

where Eq. (4) denotes the piecewise linear quantile loss function, "k" is the quantile index, "w" in the weight of the kth quantile (the *rqpd* package in R uses the default 1:3/4), and the Greek letter *mu* is the tune parameter to control the individual (neighborhood) effects.

By introducing time dummy control variables as fixed effects into the equation, our specification controls for the effect of omitted variables that are constant across neighborhoods. The spatial lag of residential burglary as another control variable is introduced to control for spatial autocorrelation, which if not controlled for, produces upward bias in estimators and inflated significance statistics (Florax & Folmer, 1992). Population density has been used in previous studies either as a control variable (Wilcox et al., 2007) or as a proxy measure of social guardianship (Breetzke & Cohn, 2013). In this study, we control for the effect of population density as it may serve as an alternative measure and competitive explanation of informal guardianship perhaps indicative of an "eyes on the street" type of informal guardianship.

We began the analysis by examining the visually examining interaction plots of concentrated disadvantage (proxy for informal guardianship) and CCTV density (formal symbolic guardianship) as well as concentrated disadvantage and police micro-station density (formal physical guardianship) on residential burglary rates. It must be noticed that an interaction term estimates the difference between the interaction or moderation effect and the sum of the independent or main effects of each IV on the DV. If positive, the moderation effect is stronger than the sum of the two independent effects, whereas if negative, the moderation effect is weaker.

After potential interaction effects were visually assessed, the panel quantile regression modelling approach was used to test our hypotheses. We focus our analysis on quantiles 0.25, 0.5, and 0.75. We then compared between quantile panel and conventional panel specifications to substantiate our results as conflicting results may be evidence of model misspecification.

Interaction plots were obtained with the use of the *flexplot* package version 0.13.7 (Fife, 2022). The CD measure index was obtained via principal component analysis (PCA) which produced individual positive and negative neighborhood scores with mean 0 and standard deviation 1. These scores were kept continuous but rescaled to range from 0 to 10 for clarity in the visual display of interaction effects and interpretation of coefficient estimates, with 0 meaning the lowest level of CD and 10 the highest level of CD. The *ade4* package version 1.7–19 in R was used to perform the PCA (Dray & Dufour, 2007). To estimate the regression quantiles for panel data we used the *rqpd* package version 0.6/r10 in R (Koenker & Bache, 2014). The *plm* package version 2.6-1 in R (Croissant & Millo, 2008) was used for calculating the conventional panel regression estimates.

For regression analyses, all variables (plus a value of 1 to adjust zeros) with the exception of CD and time were transformed to their natural logs to reduce error skewness and heteroscedasticity. Results with alpha less than 0.05 were considered statistically significant. We applied multicollinearity tests to avoid risks of Type-I and Type-II errors regarding the interaction coefficient estimates.

Table 4 Quantile panel and conventional panel linear regression results. DV: Residential Burglary Rates (Ln)

	q25	q50	q75	Panel
CD*CCTV density	−0.007	−0.024***	−0.025***	−0.018***
	(0.010)	(0.007)	(0.006)	(0.004)
CD*Police micro-station density	0.014	−0.023	−0.033**	−0.020
	(0.043)	(0.020)	(0.016)	(0.013)
CCTV density	0.058	0.185***	0.135***	0.129***
	(0.068)	(0.027)	(0.023)	(0.016)
Police micro-station density	0.330	0.213***	0.147**	0.138**
	(0.181)	(0.073)	(0.059)	(0.043)
Concentrated disadvantage (CD)	0.000	0.046***	0.039***	0.017
	(0.002)	(0.017)	(0.013)	(0.009)
Population density	0.000	−0.111***	−0.166***	−0.094***
	(0.005)	(0.017)	(0.022)	(0.012)
Year 2020	−0.019	−0.327***	−0.295**	−0.247***
	(0.078)	(0.027)	(0.024)	(0.018)
Year 2021	−0.019	−0.524***	−0.520***	−0.423***
	(0.082)	(0.026)	(0.022)	(0.018)
Spatial lag of the DV	0.000	0.277***	0.260***	0.207***
	(0.023)	(0.031)	(0.040)	(0.026)
(Intercept)	0.019	1.190***	2.305***	1.297***
	(0.089)	(0.198)	(0.238)	(0.141)
Obs	5,472	5,472	5,472	5,472

Standard errors in parentheses

***$p < 0.01$, ** $p < 0.05$

4 Results

Table 4 presents the results of our regression analyses. Results suggest to not reject H1, which predicted that concentrated disadvantage (CD) would synergistically moderate the relationship between police-monitored CCTV density and police micro-stations density with residential burglary. Likewise, results suggest not to reject H2 either, which predicted that moderation effects would not be linear across the distribution of residential burglary rates.

Starting with the relationship between police-monitored CCTV density and residential burglary, we can see a positive independent correlation (i.e., partial coefficient) between the two variables, however only in the highest quantiles of the residential burglary distribution, that is, in neighborhoods with above the average residential burglary rates. This is evidence of a higher density of CCTV in high burglary-risk neighborhoods. Evidence in support of H1 can be found in the negative sign of the interaction term, suggesting that the moderation effect is synergistic as the interactive effect of CD and CCTV density on residential burglary is stronger in less disadvantaged neighborhoods (neighborhoods with higher levels of collective efficacy). As hypothesized, we find a stronger correlation between police-monitored CCTV density and residential burglary in less disadvantaged neighborhoods, meaning there is such synergy between formal and informal mechanisms of guardianship. Notice this moderation effects shows up in all quantile specifications however only significant in the 50th and 75th quantiles of the burglary distribution. This further indicates that

Table 5 Collinearity tests

	VIF	1/VIF
CCTV density (Ln)	6.600	0.151
Police micro-station density (Ln)	6.040	0.165
Concentrated disadvantage (CD)	2.130	0.469
CD*CCTV density	7.240	0.138
CD*Police micro-station density	5.850	0.171
Population density (Ln)	1.160	0.860
Year 2020	1.330	0.750
Year 2021	1.330	0.750
Spatial lag of DV	1.150	0.872
Mean	3.650	

the moderation effect was significant in neighborhoods with high levels of residential burglary between 2019 and 2021. In sum, what these results suggest is that in neighborhoods more troubled by residential burglary, the relationship between CCTV police-monitored density and collective efficacy as proxied by concentrated disadvantage was stronger, signifying there is such beneficial synergy between these formal and informal mechanisms of guardianship. In addition, support for H2 can be seen in the notable differences between the partial coefficients and the interaction terms among quantiles, as well as in the differences with the coefficients of the conventional panel (i.e., regression to the mean).

With regards to the relationship between residential burglary and police micro-station density, we again find evidence of a positive independent correlation between the two variables (as partial coefficients). Also, as with the case of CCTV density, again the results suggest to not reject H1 as the interaction term is also negative although only statistically significant in the 75th quantile of the residential burglary distribution. What this means is that the correlation between police micro-station density and residential burglary is also stronger in less disadvantaged neighborhoods, but again only in the neighborhoods with the highest rates of residential burglary. It makes sense to expect that both mechanisms of formal guardianship, police-monitored CCTV and police micro-stations are synergistic or more interactive with collective efficacy as proxied by concentrated disadvantage and only in neighborhoods with high levels of residential burglary.

We have evidence to support H2 again as the independent correlations and the interaction term between residential burglary and police micro-station density are only significant in the upper quantiles of the DV. These independent correlations as well as the interaction terms among the three quantiles are notably different to the results of the conventional panel.

Finally, the partial coefficients of concentrated disadvantage (CD) are positive and, once again, only statistically significant in the upper quantiles of the distribution of residential burglary rates. These results suggest there are more burglaries in more disadvantaged neighborhoods, however only this difference is only statistically significant in the upper of the residential burglary distribution or neighborhoods most troubled by residential burglary –in neighborhoods less troubled by burglary, there is no independent correlation between CD and the former.

Notice how the results of the quantile panel regression differ from the bivariate correlations shown in Table 2, validating our intuition that the hypotheses had to be tested with the use a more robust method. As said above, Table 4 includes the results of the conventional

panel regression approach for comparison. We can see that this approach offers substantially different results to the quantile modeling approach. First, conventional panel results would suggest to reject H1 with respect to police micro-stations. With regards to the moderation effect of CD on the relationship between CCTV density and residential burglary, the conventional panel approach underestimates the moderation effect as evidenced by a quite smaller magnitude of the interaction term (28% smaller). The lack of significance in the CD partial coefficient, also fails to detect the effect of an independent effect of collective efficacy as proxied by CD. Finally, this approach also underestimates the main effects of population density, time, and spatiality in the DV. Table 5 shows the results of the collinearity tests indicating they are within acceptable limits.

Finally, before moving to the next section of discussion and conclusions, notice that the coefficients of the control variables in the upper quantiles are of considerable magnitude. Population density has an independent negative association with residential burglary, perhaps indicative of a sort of "eyes on the street" informal guardianship mechanism. The coefficients of the time variable with year 2019 as reference, have a negative sign meaning they are capturing the effect of the decreasing trend over time. However, again, it is in the upper quantiles where the effects of the passing of time are statistically significant. Finally, the coefficient for the spatial lag of the DV is significant and positive in the upper quantiles, meaning that high-risk neighborhoods increase residential burglary in adjacent neighborhoods and vice versa –residential burglary risk seems to spillover to adjacent neighborhoods.

5 Discussion and conclusion

Our objective has been to test whether informal guardianship proxied by concentrated disadvantage (CD) moderates the relationship between formal symbolic and formal physical mechanisms guardianship, police-monitored CCTV density and police micro-station density respectively, with residential burglary. Our argument for a moderation effect of CD on the previous relationships has been that formal guardianship, either symbolic or physical, requires some level of collective efficacy to deter burglars. To put it differently, our argument has been that formal mechanisms do not operate in isolation from the willingness to intervene in crime prevention, with the former as proxied by levels of concentrated disadvantage. We have thus explored whether formal mechanisms of guardianship benefit from social engagement when either residents or passerby make use of police-monitored CCTV systems and police micro-stations. It must be reminded that both mechanisms can be activated by neighborhood residents and/or persons walking by the neighborhood when in presence of a crime. In this respect, some level of collective efficacy that is, of willingness to cooperate in preventing crime, is necessary.

Previous studies have been more concerned with testing the main effects of different types of formal guardianship on residential burglary and have not tested the interactive nature of the relationship between formal and informal guardianship or the moderation effect hypothesis (Reynald, 2010; Tseloni et al., 2004; Vilalta & Fondevila, 2021; Wickes et al., 2017; Wilcox et al., 2007; Yue & Zhu, 2019; Zhang et al., 2007). As such, we have no specific previous studies with which to directly compare our findings.

Therefore, we contribute to the literature by offering evidence of moderation effects of CD on the relationships between police-monitored CCTV density and police micro-station density with residential burglary. As hypothesized, these moderation effects were

Table 6 Descriptive statistics of estimation sample

Variable	Mean	Std. Dev	Min	Max
Residential Burglary Rate (Ln)	0.745	0.665	0.000	4.121
CCTV density (Ln)	1.798	1.534	0.000	7.091
Police micro-station density (Ln)	0.263	0.546	0.000	3.456
Concentrated disadvantage (CD)	3.664	1.579	0.000	10.000
CD*CCTV density	6.517	6.555	0.000	47.111
CD*Police micro-station density	0.848	1.838	0.000	15.468
Population density (Ln)	9.537	0.880	1.945	12.597
Year 2020	0.333	0.471	0.000	1.000
Year 2021	0.333	0.471	0.000	1.000
Spatial lag of DV	1.790	0.398	0.000	3.359

N = 5472. The year of reference is 2019

synergistic, indicating that both mechanisms of guardianship, formal and informal, reinforce each other. However, this synergy was only detected in neighborhoods with high rates of residential burglary, meaning that this beneficial relationship between the two mechanisms may only operate in neighborhoods already suffering from high levels of residential burglary. It is important to note that the interaction between CCTV density (symbolic formal guardianship) and CD is statistically significant for the 50th and 75th quantiles of the residential burglary distribution and for the interaction between police micro-stations (physical formal guardianship) and CD it is statistically significant, although stronger, for the 75th quantile of the residential burglary distribution. What this may suggest is that the synergy is present in more neighborhoods for the case of our symbolic formal guardianship mechanism (police-monitored CCTV) than the physical formal mechanism (police micro-stations), perhaps as there are more CCTV systems than police micro-stations and thus can be more easily be activated by residents or passersby (Table 6).

One limitation in this study is precisely that we do not know how often are these formal mechanisms of guardianship being activated by the citizenry in relation to crime and in particular in relation to residential burglary. In this sense, we have measures of density rather than frequency of use, although we could expect more frequency of use of CCTV systems and police micro-stations in neighborhoods with access to such mechanisms. Likewise, we would expect a higher provision of police-monitored CCTV systems and micro-stations where they are more needed, that is, in high-risk neighborhoods. This was precisely one of our findings. Another limitation has to do with our use of measure of concentrated disadvantage as a proxy of collective efficacy. Our component index of concentrated disadvantage is not a direct measure of trust or social cohesion at the neighborhood level, but rather a direct measure of a necessary condition for collective efficacy to operate, as the collective efficacy theory literature shows extensively. Because of the strong independent correlation between socioeconomic composition and collective efficacy, and mediation effect of the latter on the relationship between the former and crime, many studies have advanced the literature under the premise that neighborhood variations in social composition are able to represent neighborhood variations in informal social controls and social cohesion and trust (Schaefer & Mazerolle, 2017; Vilalta et al., 2021b; Wilcox et al., 2007; Zhang et al., 2007).

To conclude, our findings carry two main implications for future research on guardianship against residential burglary and crime prevention policy. First, as nothing is more fundamental in criminological research than resolving the crime problem, our finding that

Table 7 Concentrated Disadvantage Oblique component: Factor loading

Variable	Factor loading	KMO statistic
Population w/o medical health services (%)	0.535	0.780
Population 15 years or older without schooling (%)	0.583	0.660
Dwellings w/o computer and internet access (%)	0.611	0.620

formal and informal mechanisms of guardianship operate interactively means that better results can be expected if formal and informal mechanisms of guardianship are used and taught to be used in combination. Second, our finding that neither main effects nor interaction effects are constant across the residential burglary distribution, means that we should not expect neither similar nor average effects of formal and informal mechanisms in all neighborhoods. Rather there is a geography of the effects of guardianship on crime that is worth to explore in more detail in future studies.

Appendix

See Table 7.

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