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Danger zone: Land use and the geography of neighborhood crime

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ABSTRACT

This paper examines the impact of residential density and mixed land use on crime using a high-resolution dataset from Chicago over the period 2008–2013. I employ a novel instrumental variable strategy based on the city's 1923 zoning code. I find that commercial uses lead to more street crime in their immediate vicinity, particularly in more walkable neighborhoods. However, this effect is strongly offset by population density; dense mixed-use areas are safer than typical residential areas. Additionally, much of the commercial effect is driven by liquor stores and late-hour bars. I discuss the implications for zoning policy.

1. Introduction

Urban crime imposes a considerable economic hardship on city governments, businesses, and residents. In 2013, the City of Chicago spent over $1.3 billion on policing, and robberies alone cost city residents an estimated $500 million.[1] Crime has a substantial impact on neighborhood growth, racial segregation, and property values (Morenoff and Sampson, 1997; Pope and Pope, 2012). Violent crime patterns drive firms' location decisions within cities, affecting employment opportunities and access to amenities for city residents (Rosenthal and Ross, 2010). Crime levels even influence trends in suburbanization and urban revitalization, affecting the long-run growth of cities (Cullen and Levitt, 1999; Schwartz et al., 2003).

Policymakers are eager to combat city crime in an attempt to encourage urban revitalization, boost the tax base, and spur the emergence of neighborhoods attractive to increasingly coveted "creative class" workers. Many cities have embraced the notion that land use regulations can be used to cultivate walkable, vibrant neighborhoods that are naturally self-policing. The idea that urban form can shape pedestrian traffic and the social fabric of neighborhoods in a crime-controlling manner stems from the influential work of Jacobs (1961), which has recently been subject to renewed attention from policymakers, academics, and professional planners.[2] During his term, Mayor Bloomberg presided over the rezoning of 37% of New York City, much of it for dense, mixed-use developments encouraged by the theories of Jane Jacobs (Silverman, 2013). Many other major cities, such as Houston, Texas and Vancouver, British Columbia, have embraced the high-density, mixed-use development trend (Sarnoff and Kaplan, 2007; Punter, 2007). Even smaller cities such as Sarasota, Florida have pursued zoning changes designed to mitigate persistent crime problems (Carter et al., 2003).

While popular in practice, these ideas surrounding the relationship between land use and crime have received insufficient empirical scrutiny. Economists have largely ignored the role of land use patterns in explaining intra-metropolitan variation in crime (O'Flaherty and Sethi, 2014).[3] Criminologists counter Jacobs' theories with the claim that mixed uses and high residential density generate more contact between potential offenders and potential victims. The "routine activities" theory of Cohen and Felson (1979) argues that direct-contact predatory crime requires the "convergence in space and time of *likely offenders, suitable targets* and the *absence of capable guardians*," which is more likely to occur in high-density, mixed-use areas. Stark (1987) argues that mixed

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[1] The budget estimate comes from the City of Chicago's 2014 Budget Overview. McCollister et al. (2010) estimate that the tangible and intangible costs of a robbery to victims and the justice system amount to $42,310; there were 11,780 reported robberies in Chicago in 2013.

[2] See, e.g., Duany et al. (2010) and Glaeser (2011).

[3] Notable exceptions include studies of the impact of housing vacancies and the demolition of high-density public housing, which I discuss in detail below.

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uses and high density result in greater transience, anonymity, and "moral cynicism among residents," reducing neighborhood collective efficacy. Studies from the criminology and sociology literatures are largely descriptive, with limited attention to causal identification.

In this paper, I attempt to mediate this theoretical dispute and document the causal effects of proximate and nearby commercial uses, neighborhood walkability, and residential density on patterns of street crime. I also examine the extent to which these forces interact. To do so, I develop a high-resolution dataset of land use in Chicago using a comprehensive 2005 land use survey supplemented with data from Walkscore.com as well as exact locations of every restaurant, (late-hour) bar, and liquor store in the city. I combine this with detailed, spatially-referenced crime data covering all reported street crime incidents over the period 2008–2013. To address unobserved neighborhood characteristics and reverse causality, I employ an instrumental variables approach, using the city's 1923 zoning code as an instrument for modern land use. I show that historical zoning is a strong predictor of modern land use. I validate the assumption of exogeneity using data on the locations of homicides, gangs, juvenile delinquency cases, and low-income neighborhoods in the 1920s to test for the persistence of historical confounders. To identify the impact of specific commercial uses, I apply a spatial matching approach, examining how the level of crime differs within pairs of street segments that differ in their land use composition but are so proximate spatially that they arguably share similar unobservable neighborhood characteristics.

I find that commercial activity leads to substantially higher street robbery and assault rates, particularly in more walkable neighborhoods. However, this effect decays and then reverses at higher densities, so that dense, mixed-use areas actually exhibit lower crime rates than typical residential areas. Furthermore, crime rates are weakly declining with residential density, a striking finding given that larger cities are known to have higher crime rates (Haynes, 1973; Glaeser and Sacerdote, 1999). My results are strongly consistent across models based on three different identification strategies (selection-on-observables, instrumental variables, and spatial matching). The nonlinear relationship between commercial activity, walkability, and density is a novel finding which has eluded previous research on this topic. I interpret this result as a partial vindication of both Jane Jacobs and the routine activities theory: While commercial activity facilitates crime by generating contact between potential offenders and victims, a critical mass of pedestrian traffic appears to deter crime. I find that the positive effect of commercial uses on street crime is almost totally driven by liquor stores, restaurants, and bars (particularly late-hour bars), with the sizable impact of bars largely concentrated between the hours of 2 a.m. and 6 a.m.; restaurants and liquor stores appear to drive crime throughout the day.

These findings potentially have implications for local government policymaking. My results suggest that zoning which favors higher residential density could improve neighborhood safety. They also suggest that zoning which allows for mixed use structures may be preferable to more restrictive rules that aim for strictly residential or commercial use. These policy prescriptions are consistent with other recommendations advanced by economists, emphasizing how regulations favoring higher densities and mixed uses lead to lower housing costs and lower spatial mismatch between jobs and job seekers (Glaeser and Ward, 2009; Quigley and Raphael, 2005; Gobillon et al., 2007).

In addition to providing new results on the nonlinear relationship between land use and crime, this study also contributes to the research program in criminology which attempts to explain the phenomenon of crime "hot spots." One of the primary motivations for the study of land use and crime is the striking spatial heterogeneity of crime rates, both between and within neighborhoods. Crime is typically concentrated on a very small subset of city blocks and intersections, which have been dubbed "hot spots" (Weisburd et al., 2012).[4] This has prompted many researchers to explore place characteristics that could result in the formation of hot spots. More broadly, my finding that land use is a major determinant of crime patterns further establishes the importance of understanding this relationship.

2. Previous literature

Empirical studies of urban crime by economists have largely focused on explaining temporal and inter-metropolitan variation in crime rates; a smaller literature has analyzed intra-metropolitan variation, which appears to be substantially greater (O'Flaherty and Sethi, 2014). A number of studies analyze crime around foreclosed properties, which may affect crime by altering patterns of street traffic and neighborhood monitoring. Ellen et al. (2013) show that vacancies cause a general increase in crime in their immediate vicinity using microdata and a measurement approach very similar to that employed in this paper. Lacoe and Ellen (2015) show that vacancies may shift crime from the street into residences, consistent with the notion that less pedestrian traffic decreases the returns to street crime. Stucky et al. (2012) and Cui and Walsh (2015) show that residential foreclosures increase violent crime nearby.

A number of studies have documented other spatial determinants of crime patterns. Phillips and Sandler (2015) show that public transit influences the spatial distribution of crime by affecting the transportation costs facing potential offenders; their findings are consistent with the routine activities theory. Aliprantis and Hartley (2015) examine the demolition of high-density public housing and find that it leads to a sizable reduction in nearby violent crime. A number of studies have examined how low-income housing subsidies, which may alter neighborhood composition, affect local crime. Lens (2013) examines housing subsidies in New York City but finds little impact, while Lens (2014) finds a small negative effect in cities but no effect in suburbs. Freedman and Owens (2011) find that investments in low-income housing in poorer neighborhoods lead to declines in robberies and assaults; this may be due to increased development and reduced vacancies resulting in greater neighborhood monitoring.

Also relevant to my study is the (largely descriptive) literature in criminology and sociology on the relationship between crime and land use, most of which focus on neighborhood-level crime rates. Wright and Decker (1997) and Bernasco and Block (2009) find that robbers frequently offend near their homes. Browning et al. (2010) study the relationship between crime and commercial and residential density in a sample of census tracts from Columbus, Ohio. They find that, at low levels, an increase in a variable measuring commercial/residential density is associated with more crimes; at high levels, this relationship becomes negative. In Indianapolis, Stucky and Ottensmann (2009) find that robberies are more common in more commercial neighborhoods. Sampson (1983) argues that high residential densities will lead to more violent crime. Using data from Cleveland, Roncek and Maier (1991) document that city blocks containing bars see substantially more violent and property crime. Teh (2008) uses an event-study methodology to show that the introduction of liquor stores into

[4] Sherman et al. (1989) find that 3% of addresses/intersections in Minneapolis are responsible for 50% of calls to the police. Braga et al. (2010) find a similar result for gun crime in Boston and show that these hot spots are persistent over time. This pattern has been documented in Seattle and Tel Aviv-Jaffa as well, suggesting that this is a general feature of urban areas (Weisburd et al., 2004; Weisburd and Amram, 2014).

Los Angeles neighborhoods with low socioeconomic status is associated with more violent and property crime.

Bernasco and Block (2011) and Anderson et al. (2013) use a microdata approach and are most closely related to the present work. Anderson et al. (2013) use zoning as a proxy for land use and study the relationship between crime, land use, and other built environment characteristics. They measure the number of crimes within 100 and 250 m of each of 205 blocks in Los Angeles County. They find that residential zoning is associated with less crime than mixed-use zoning, and that commercial zoning is associated with substantially more crime than mixed-use zoning. Their identification strategy relies on matching blocks by demographics, which is unlikely to yield reliable conclusions, as there is considerable variation in crime even among matched blocks.[5] Anderson et al. (2013) use block zoning to predict counts of crimes within 250 m, ignoring the fact that these crimes will be influenced by land use from other nearby blocks, inducing non-classical measurement error. My approach, more in line with that employed by Ellen et al. (2013) to study foreclosures, avoids this problem.

Bernasco and Block (2011) study the spatial pattern of street robberies in Chicago, focusing on small bars, fast-food restaurants, liquor stores, and laundromats. They find that every commercial use they measure has a positive relationship with the number of robberies. While the best study to date on the role of specific commercial uses, it relies on a simple set of control variables and fails to separate the effect of specific uses from the general impact of being in a commercial area, so it is not possible to determine if specific uses (e.g., bars) are themselves causing elevated crime rates.

3. Data

This section describes the eight components of the dataset compiled for this paper. Land use data is drawn from two sources: A comprehensive 2005 survey of land use in Chicago and a registry of business licenses. I supplement this with data on the accessibility of commercial amenities from Walkscore.com. Modern demographic data is derived from the 2010 Decennial Census as well as the American Community Survey. Crime data is derived from incident report records provided by the Chicago Police Department. Historical zoning data was geocoded from the original 1923 zoning ordinance and associated maps. Historical demographic data comes from the 1920 Decennial Census and the 1938 Local Community Fact Book. Historical homicide data is taken from the Chicago Historical Homicide Project. Data on the locations of gangs in the mid-1920s was taken from Thrasher (1927). Historical land use data was geocoded from a comprehensive 1922 land use survey.

3.1. Land use

My primary land use data comes from a comprehensive 2005 land cover survey conducted by the Chicago Metropolitan Agency for Planning (CMAP). From the CMAP classification I derive the following mutually exclusive and exhaustive land use categories: Single-family residential, multi-family residential, commercial (including residential with ground-level retail), industrial, institutional, open space, transportation, infrastructure, vacant, and under construction. Virtually all of the land in the city is coded as residential, commercial, industrial, institutional, or open space. The variables included in the analysis are discussed in Section 4.2.

To analyze the role of specific commercial uses, I obtained data on restaurants, bars, liquor stores, and late-hour bars (which are permitted to stay open past 2 a.m.) from the registry of business licenses maintained by the Chicago Department of Business Affairs and Consumer Protection over the period 2008–2013. This registry includes coordinates which were used to geocode the establishments. I use the particular set of licenses held by an establishment to determine whether it is a restaurant, bar, liquor store, or late-hour bar.

In addition to general and specific land uses, I employ data on neighborhood “walkability” obtained from Walkscore.com, which rates Chicago as the sixth most walkable city in the US. Walkscores range from 0 to 100 and measure the extent to which errands and activities involving commercial uses can be accomplished on foot. More walkable areas should on average have higher levels of pedestrian traffic, all else equal. The scores are interpolated from a quarter mile-spaced mesh of observed values. Since they proxy for walking convenience, they vary smoothly over normal walking distances of less than one mile. Neighboring points on the mesh typically differ by only 2–3 points on the 0–100 Walkscore scale.

3.2. Demographics

Demographic data is drawn from the 2010 Decennial Census and the 2006–2010 American Community Survey. The 2010 Census provides total population counts, counts by race and Hispanic/Latino origin, age composition, and counts of housing units and tenure status at the block level. The 2006–2010 American Community Survey provides data on median household income, counts of individuals on public assistance, and poverty status. Census data and associated GIS maps were taken from the National Historical Geographic Information System (MPC, 2016).

3.3. Crime

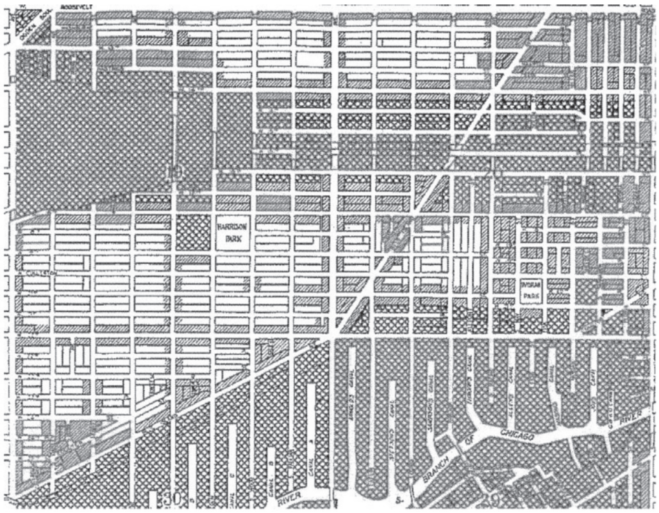
Information on crimes is drawn from a publicly-accessible database of crime incident report data provided by the Chicago Police Department’s Citizen Law Enforcement Analysis and Reporting system. It includes every instance of robbery, battery, and assault over the period 2008–2013 for which an incident report was filed. Robbery is defined as the intentional taking of property from a person “by the use of force or by threatening the imminent use of force.” A person commits battery if they knowingly cause “bodily harm to an individual” or make “physical contact of an insulting or provoking nature with an individual.” A person commits an assault when they knowingly engage in “conduct which places another in reasonable apprehension of receiving a battery.”

The publicly-available data includes coordinates corresponding to the most proximate address, which were used to geocode the crimes.[6] Crucial for my study is the fact that each incident report includes a brief description of the location of the crime, such as sidewalk, apartment, or small retail store. This location description allows me to isolate street crimes from those occurring inside businesses or residences; my analysis focuses solely on street crimes.

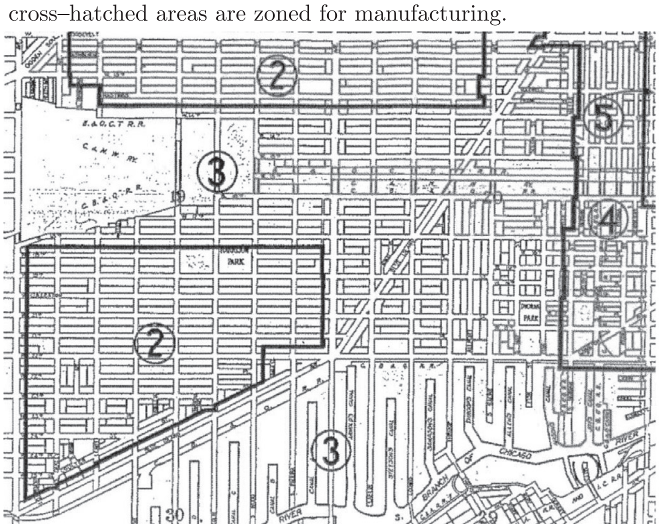
3.4. Historical zoning

To deal with potential confounding between land use and crime, I adopt an instrumental variable approach, using Chicago’s original 1923 zoning code as an instrument for modern land use. This was the city’s first comprehensive zoning ordinance, and it established districts regulating both land use types (“use districts”) and building density (“volume districts”). Four use districts were created: Residential (single-family housing), apartment, commer-

[5] In my data, the variance of crime rates is actually higher among blocks matched on racial composition or poverty status than it is across the city as a whole.



(A) Portion of 1923 use zoning map. Unhatched areas are zoned for apartments, hatched areas are zoned for commercial uses, and cross–hatched areas are zoned for manufacturing.



(B) Portion of 1923 volume zoning map. Zone 2 is the lowest density area depicted here, accommodating low–rise apartment buildings. Zone 5 is the highest density area, allowing for skyscrapers over 20 stories.

Fig. 1. 1923 zoning maps.

cial, and manufacturing. Fig. 1a provides a sample of the 1923 use zoning map.

Volume districts imposed restrictions on maximum lot coverage, aggregate volume, and height. Five volume districts were established, with district 1 restricted to the lowest density while district 5 permitted skyscrapers. Fig. 1b provides a sample of the 1923 volume zoning map. Shertzer et al. (2016a) demonstrate that this zoning ordinance had a substantial causal effect on the spatial evolution of land use patterns in Chicago. This makes the zoning code a powerful instrument, as I document in Section 4.3.2.

3.5. Historical land use

In Section 4.3.3, I use historical land use data as part of a test for persistent unobservable neighborhood characteristics which may influence crime. I geocoded this data from a comprehensive 1922 land use survey conducted by the Chicago Zoning Commission to inform the process of drafting the 1923 zoning ordinance. This data contains the location of every commercial establishment, warehouse, and manufacturing use in the city, with the latter subdivided into five subcategories. It also includes the location and number of stories for every building with four or more stories.

3.6. Historical demographics

During the late 1920s, a group of sociologists at the University of Chicago divided the city into 75 mutually exclusive and exhaustive “community areas.” These were considered “natural areas,” the divisions reflecting distinct and identifiable clusters of related neighborhoods (Bulmer, 1986). 49 of these community areas overlap my sample; I use fixed effects based on these to partially mitigate biases due to unmeasured neighborhood characteristics.

The Chicago Recreation Committee prepared an extensive handbook on community area characteristics in 1930 and 1934 for use by civic and social agencies; the 1938 Local Community Fact Book that resulted contains data on the share of households receiving public assistance and the rate of male juvenile delinquency court petitions per 100 males aged 10–16 over the period 1927–1933, which I utilize in Section 4.3.3 to argue for the validity of my instrumental variables strategy (Wirth and Furez, 1938). Historical data on tract-level population and racial composition comes from the 1920 Decennial Census. The data and associated GIS maps were taken from NHGIS.

3.7. Historical crime and gang activity

In Section 4.3.3, I compare historical and modern patterns of crime to argue for the validity of my instrumental variables strategy. I draw historical homicide data from the Chicago Historical Homicide Project, which digitized a continuous record of approximately 11,000 homicide cases maintained by the Chicago Police Department over the period 1870–1930 (Bienen and Rottinghaus, 2002). Many of these records contained an address for the location of the crime. 4528 of these were geocoded to a specific street address, while another 742 were matched to the nearest street intersection. Of these 5270 homicide cases, 4290 are dated between 1910 and 1930.

A pioneering study by Frederic M. Thrasher examined 1313 gangs in Chicago over the period 1923–1926. The locations of these gangs were recorded in a map, a portion of which is shown in Fig. 2. I digitized these gang locations for use in Section 4.3.3. While not all of these gangs engaged in criminal activity, many did, and their distribution closely matches that of other crime proxies as well as data from the historical record on the location of criminal activity in this era (Shaw et al., 1929).

4. Methodology

In Section 4.1, I define and motivate my unit of observation. In Section 4.2, I describe the basic empirical approach. In Section 4.3, I outline my instrumental variable strategy and provide evidence for the relevance and exogeneity of the instruments. In Section 4.4, I present a solution to the problem of identifying the effects of specific commercial uses based on matching proximate observations.

4.1. Unit of observation

The goal of the empirical analysis is to determine the effect of proximate and nearby commercial uses on crime, as well as the influence of population density and the interaction of these effects.

[6] There is no evidence that crimes were coarsely geocoded to, e.g., the nearest street intersection.

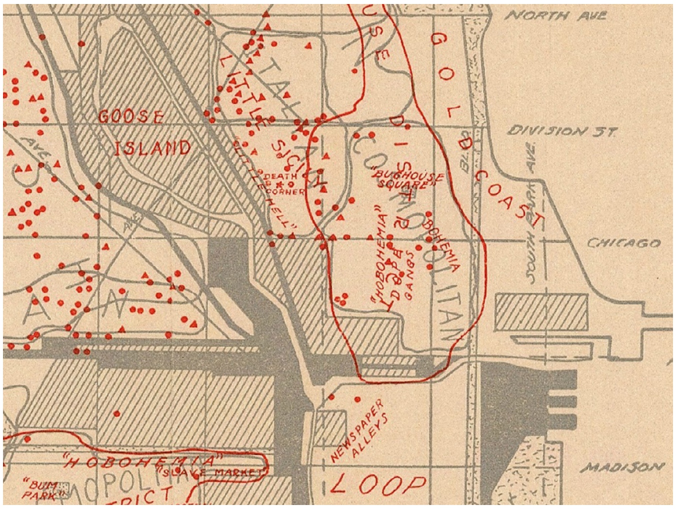


Fig. 2. Portion of Chicago's gangland map, 1923–1926. Map depicts gang and drug activity in the near north side area of Chicago circa 1923–26. This area is now dominated by luxury residential and retail activity. Taken from Thrasher (1927).

Given a small street segment, I want to determine how commercial uses on the street segment influence crime, and contrast this effect with that of more distant commercial uses. Theory suggests that commercial uses may affect crime in their immediate vicinity by increasing pedestrian traffic and contributing to social norm enforcement via monitoring by business proprietors. Commercial uses may have an effect over a longer range by generating street traffic that spills over into neighboring residential areas. The ideal unit of observation should capture crimes and their immediate surrounding land uses while also measuring proximity to neighboring land use types. For example, crimes that occurred in front of a commercial establishment should be distinguishable from crimes that occurred in front of a home but down the street from a commercial use, and these latter crimes should be distinguishable from crimes that occurred in isolated residential areas.

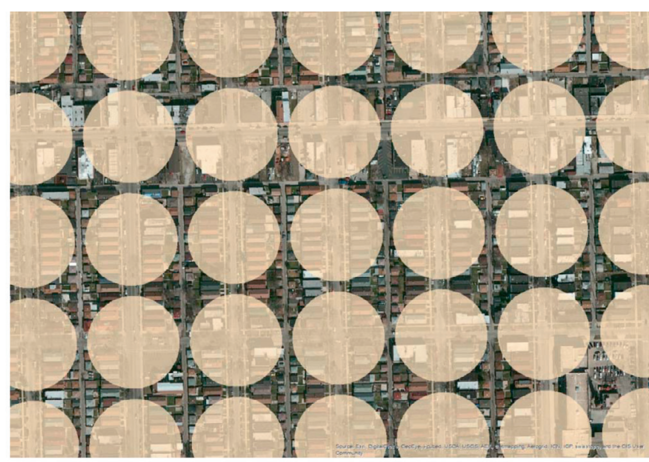
To accomplish this, I aggregate crimes within small (150-ft-radius) street-centered circles and measure the land use within these circles. The circles are small enough so that the land use captured is only that which immediately surrounds the location of the crimes.[7] To analyze the spatial range of effects, I also measure land use in an ring extending 500 ft from the boundary of each circle. This captures the effect of "down the street" land uses. An example is given in Fig. 3.

These (non-overlapping) circles are centered on points selected along the street grid. Ideally, my sample would cover the entire street area in the portion of the city for which I have data. However, this is not feasible, since it would be impossible to avoid generating circles that overlap. The algorithm I use approximates this ideal:

1. Start with all street intersections and midpoints.
2. Drop midpoints within 300 ft of an intersection.
3. Drop intersections within 300 ft of each other.
4. Randomly sample points on portions of the street grid that are more than 300 ft away from any remaining points.

The first three steps of this algorithm yield a dense, regular array of sample points in the majority of the city, due to the ubiquitous rectangular grid street system. An example is given in Fig. 4a.

Fig. 3. Sample unit of observation with ring. Each observation is a combination of a circle (inner, beige) and a surrounding ring (outer, blue). Circle radius is 150 ft, with the ring extending 500 ft from the boundary of the circle. Land use variables are calculated as land cover shares separately for both the circle and ring. Population density and other demographic variables are interpolated from block- or block-group-level counts to the combined circle-ring area, capturing approximately the number of individuals living within the outer boundary. Walkscore is averaged over each circle. Crimes and specific land uses (restaurants, bars, late-hour bars, and liquor stores) are counts aggregated to the circle level. Crime rates are calculated per 1000 residents of the combined circle-ring area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



(A) Sampling in regular portion of the street grid.

(B) Sampling in irregular portion of the street grid.

Fig. 4. Sampling patterns.

[7] This method also ensures that the land use on the sides of the street opposite the location of the crime are effectively captured, which is not the case when census blocks are used as the unit of analysis.

In the portions of the city with an irregular street grid, the sample points are less densely packed. An example is given in Fig. 4b.

My circle-level data consists of crime rates as well as land use (including the fraction of land covered by commercial, residential, and industrial uses and counts of specific business types). I also measure land use and businesses contained in the 500-ft ring surrounding each circle. I measure demographic data at the combined circle-ring area via areal interpolation from census blocks and census block-groups.[8] Since census blocks tend to be smaller than city blocks in Chicago, this interpolation should accurately capture population composition.

My data covers the portion of Chicago south of Irving Park Road and north of 87th Street. This is approximately the middle two-thirds of the city and it includes the central business district, the historic Black Belt, and many of the largely black or Hispanic enclaves that have developed since the early twentieth century.

4.2. Estimation: baseline specification

The estimation equation is

$$\begin{aligned} y_i = {} & \beta_0 + \beta_1 \%com_i + \beta_2 ring\%com_i + \beta_3 popdensity_i \\ & + \beta_4 popdensity_i * \%com_i + \beta_5 walkscore_i \\ & + \beta_6 walkscore_i * \%com_i + \beta_7 walkscore_i * popdensity_i \\ & + \beta_8' l_i + \beta_9' d_i + \beta_{10}' g_i + \beta_{11}' CA_i + \epsilon_i \end{aligned} \tag{4.1}$$

The main outcomes of interest y_i are rates of street robbery and assault per 1000 residents over the period 2008–2013.[9] These capture the most ubiquitous forms of serious street crime; other serious street crimes are far less common.[10] The primary explanatory variables of interest are: % commercial, the percentage of land in each circle occupied by commercial uses (including apartment buildings with ground-level retail), ring % commercial, the percentage of each surrounding ring occupied by commercial uses, population density (total number of interpolated from census blocks to the combined circle-ring level), and Walkscores; all of these variables are standardized.

The simplest specifications include % commercial, ring % commercial, and population density as the primary explanatory variables (in addition to the other land use, demographic, geography, and community area fixed effects described below). These are included in all specifications. In some specifications, I add Walkscores or an interaction between density and commercial use. The fullest specification includes all two-way interactions between % commercial, population density, and Walkscores. l_i contains other land use control variables, including the percentage of the circle and ring occupied by single-family residences and industrial uses. These are the primary land use variables, and I instrument for all of them in the second part of the empirical analysis.

l_i also contains a variety of auxiliary land uses measures. It includes the percentage of the circle and ring occupied by institutional and large-scale transportation uses as well as the percentage that is vacant or open space. I include an indicator for whether or not the circle contains a street intersection; Wright and Decker (1997) document that armed robbers prefer to commit offenses near intersections to allow for an easier escape. White (1990) suggests that neighborhood permeability, defined as access to major traffic arteries, may have a positive impact on crime. To account for this possibility, I include a measure of street density, an indicator for location on a major street, a polynomial in the distance to a major street, and the percentage of the circle and ring occupied by a major transportation corridor. The concentration of crime around bus stops is well documented (see, e.g., Loukaitou-Sideris, 1999), and bus stops are frequently located along streets occupied by commercial uses, so I include counts of bus stops in each circle. Following the literature on the importance of vacancies, I include the percentage of housing units which are vacant and the percentage which are owner-occupied.

d_i includes a number of demographic control variables, including the percentage of the population that is black, Hispanic, or under 18, the percentage of households with members over the age of 65, and the average household size. The percentage of households on public assistance is included, as is the share of households falling into each of seven bins defined by household income relative to the poverty level. g_i includes a number of variables measuring geographic factors, such as the distance to the central business district, Lake Michigan, the nearest river, nearest railroad, nearest park, and the nearest CTA station. Finally, CA_i is a vector of community area fixed effects used to mitigate the bias due to unmeasured neighborhood characteristics. Estimation of the baseline linear model uses ordinary least squares.[11] Standard errors are clustered at the police beat; there are 194 clusters.[12]

4.3. Identification: instrumental variables

There are a number of reasons to suspect that unobservable confounders or reverse causality between crime and land use are biasing the results obtained using the baseline approach. There is substantial evidence that crime rates are related to (difficult-to-measure) neighborhood social cohesion (Sampson et al., 1997; Morenoff et al., 2001; Martin, 2002). Homeowners have substantial incentive to exert control over changes in nearby land use patterns which may affect their property values (Fischel, 2001). The extent to which they can do so depends on neighborhood social cohesion, since influencing the political process of zoning requires the concerted effort of many residents, and this may be undermined by free-riding. Thus, neighborhood social cohesion may confound the relationship between land use patterns and crime.

Furthermore, reverse causality is a concern because high levels of crime or rising crime rates may alter the incentives determining land use patterns. For example, crime may discourage the construction of new high-density residences, or it could lower property values, encouraging the encroachment of industrial or commercial uses into previously residential areas. It could also have the opposite effect, diminishing the incentives for new business formation. Rosenthal and Ross (2010) document this kind of sorting behavior by entrepreneurs.

To address the potential endogeneity of land use patterns, I adopt an instrumental variables strategy, using Chicago's 1923 zoning code to instrument for modern land use. I show in Section 4.3.2 that the 1923 zoning code is strongly related to land use patterns today, and Shertzer et al. (2016a) provides strong evidence to suggest that zoning shaped the evolution of land use patterns in the city. Since the zoning code predates my current data by over 80 years, this insulates the instrument from the reverse causality problem discussed above. Furthermore, criminogenic fac-

[8] Counts at the block and block-group level are assigned to my observations based on area of overlap; thus, if the combined circle-ring area overlaps half of a block, then half of that block's population will be assigned to the observation. Observations overlapped an average of 21 census blocks and 3 census block-groups.

[9] I aggregate assaults and batteries due to the hierarchical nature of incident reporting: Batteries are a class A misdemeanor in Illinois, so an incident involving an assault and a battery will be classified as a battery, since assaults are a (lower) class C misdemeanor. As "assault" is the more commonly used term, I adopt it to describe both assaults and batteries.

[10] Street homicides are very rare in my sample (occurring in fewer than 5% of observations), and reported street rapes are even rarer, so I do not analyze these outcomes.

[11] Results using a Poisson model are qualitatively similar.

[12] Clustering at the community area level yields very similar results.

Table 1
IV first-stage statistics.

	SW F	SW F p-value	SW χ^2	SW χ^2 p-value
% commercial	15.022	0.000	303.746	0.000
Ring % commercial	6.898	0.000	139.476	0.000
Population density	2.854	0.000	57.711	0.000
Population density × % commercial	3.025	0.000	61.173	0.000
Walkscore	5.381	0.000	108.811	0.000
Walkscore × % commercial	5.444	0.000	110.075	0.000
Walkscore × population density	3.549	0.000	71.760	0.000
% industrial	7.810	0.000	157.907	0.000
Ring % industrial	10.485	0.000	211.996	0.000
% single-family residential	14.845	0.000	300.170	0.000
Ring % single-family residential	11.383	0.000	230.160	0.000
Observations: 19,330				

Statistics calculated using Sanderson and Windmeijer (2016) approach for linear IV models with multiple endogenous variables. % commercial, % industrial, and % single-family residential are land cover shares within each 150-ft-radius circle. Ring % commercial, ring % industrial, and ring % single-family residential are land cover shares within a 500-ft ring around each circle. Population density is interpolated from block-level counts to the combined circle-ring area. Walkscore is averaged over each circle.

tors that may have been related to zoning in the 1920s are unlikely to have persisted to the present due to the dramatic and widespread change in the socio-economic composition of neighborhoods over time. Below, I show how a wide range of proxies for crime in the 1920s bear virtually no relationship to crime today, suggesting that unobservables influencing crime today are unlikely to be related to zoning (net of zoning's influence on present-day land use).

Two other factors merit consideration. To the extent that policing behavior is correlated with land use due to a common excluded cause, this IV strategy will isolate the effect of land use patterns on crime. If land use patterns directly affect policing behavior, as they likely do, then this approach identifies a "net" treatment effect, where police behavior is one causal channel through which land use affects crime. Land use also influences residential sorting behavior; individuals with a higher propensity to commit crime may sort towards areas with certain land use characteristics. If this is the case, sorting is another channel through which land use affects street crime. Differences in neighborhood composition or policing behavior induced by land use patterns are not violations of the exclusion restriction, they are simply components of the overall treatment effect. Since the goal of the analysis is to understand how land use influences street crime, capturing the direct effect as well as indirect impacts through induced changes in policing behavior and individual sorting is essential.

4.3.1. Estimation and instrument set

I reestimate the models from Section 4.2 using two-stage least squares with historical zoning instruments for commercial and industrial use, population density, and walkability. As before, standard errors are clustered at the police beat. The instrument set includes the percentage of each circle zoned for commercial, manufacturing, and residential use in 1923 as well as the percentage falling into volume districts 1, 2, and 3, with the omitted density category comprised of districts 4 and 5. The same variables are computed for the ring around each circle. Interactions between use and density variables are included since use zoning had heterogeneous effects across density levels (and vice versa). The distance to the nearest commercial and manufacturing zone is included as well.

4.3.2. Relevance

Table 1 presents the first-stage F and χ^2 statistics for each endogenous variable. Since there are multiple endogenous variables, standard first-stage statistics are unreliable; I use the Sanderson and Windmeijer (2016) adjusted statistics to provide a correct test for weak instruments. As is clear from the table, historical zoning is a strong predictor of modern land use.[13]

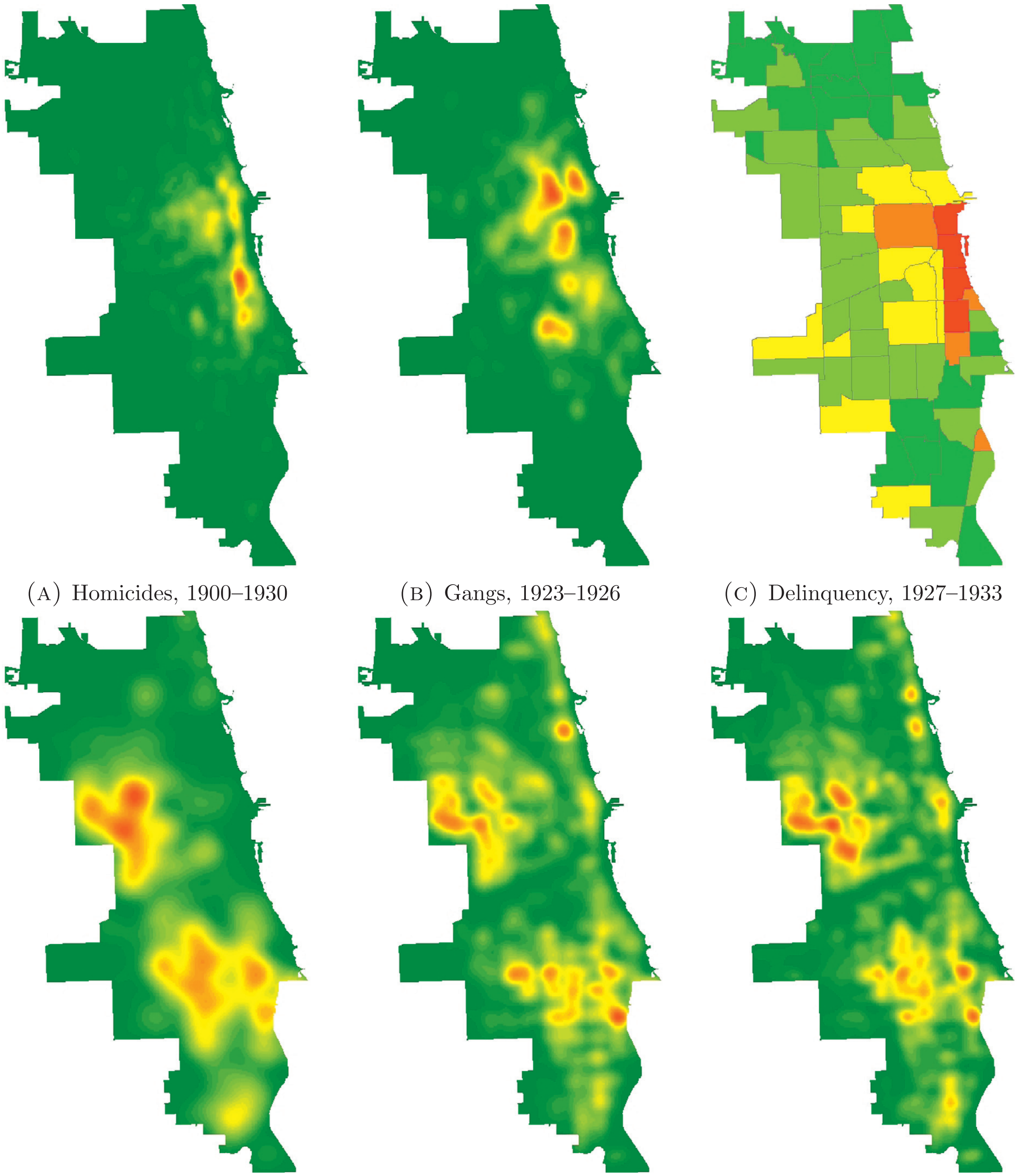
4.3.3. Exogeneity

The validity of the exclusion restriction requires that zoning's impact on present-day crime is entirely mediated through its impact on present-day land use. If unobservable neighborhood characteristics which may have influenced crime and zoning in 1923 have persisted to the present, this would violate the exclusion restriction. In this section, I argue that large-scale demographic changes preclude this possibility, and I use historical data on crime, gangs, land use, and demographics to rigorously test for the persistence of unobservable confounders.

Substantial neighborhood transformation has taken place throughout Chicago over the past 90 years. Deindustrialization and suburbanization following World War II caused a dramatic shift in the demographics of the city; Chicago lost nearly 22% of its population between 1960 and 1990 (Hunt and DeVries, 2013). Bursik and Webb (1982) document substantial demographic changes in Chicago over the period 1940–1970 which were strongly related to changes in delinquency. Many of the most violent enclaves today are located in outlying areas of the city that were largely undeveloped in 1920.

The unique range of data available for Chicago allows me to present some quantitative evidence of neighborhood change. My data includes georeferenced historical homicide cases (spanning 1870–1930 but largely concentrated between 1910–1930) and gang activity (1923–1926). It also includes rates of juvenile delinquency court petitions (1927–1933) and shares of households on public assistance (1934) recorded at the community area level. Fig. 5 presents choropleths of these historical homicides, gangs, and juvenile delinquency rates in the first three panels. All of these crime indicators were concentrated in and around the central business district and the area immediately south of the CBD; this is strongly consistent with the historical record, which documents that crime was highest in these relatively poor areas (Shaw et al., 1929). If the factors that led to high crime in the early twentieth century were persistent, one would expect to find that historically high-crime areas continue to see a relatively high level of crime today. For com-

[13] The full first-stage regression table can be found in the appendix. For further analysis, I direct the interested reader to Shertzer et al. (2016a). That paper combines the present data with historical census data from Shertzer et al. (2016b) to study the long-run effects of zoning on land use patterns in Chicago. The results indicate that zoning fundamentally altered land use patterns throughout the city.



(A) Homicides, 1900–1930 (B) Gangs, 1923–1926 (C) Delinquency, 1927–1933

(D) Homicides, 2008–2013 (E) Robberies, 2008–2013 (F) Assaults, 2008–2013

Fig. 5. The changing geography of crime in Chicago. Red-green color scale with red indicating greater relative intensity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

parison, I present similar figures for modern street homicides, robberies, and assaults. The spatial distribution of crime has changed dramatically, with all of these crimes concentrated in western and far south neighborhoods of the city. Most of the poorer, higher crime areas of the 1920s are now relatively wealthy and safe.

Table 2 presents correlations between four historical crime proxies (rates of homicide, gangs, delinquency, and public assistance), three modern street crime rates (homicide, robbery, and assault) and the share of households on public assistance in 2010. The four historical crime proxies are strongly correlated with each other, as are the modern analogs. However, the correlations between these historical and modern variables are small in magnitude and distributed symmetrically around zero, with an average of -0.03. Historical measures of crime are essentially unrelated to modern crime rates, and the correlation between rates of households on public assistance over time is -0.01.[14] This strongly sug-

[14] The largest of these correlations (0.24) is actually smaller than what one would expect if the variables were statistically independent. A simple simulation provides verification of this; code available upon request.

Table 2
Correlation between modern crime and historical crime proxies.

	Homicides 1870–1930	Gangs 1923–1926	Delinquency 1927–1933	Families on relief 1934	Robberies 2008–2013	Assaults 2008–2013	Homicides 2008–2013
Homicides, 1870–1930							
Gangs, 1923–1926	0.43						
Delinquency, 1927–1933	0.87	0.48					
Families on relief, 1934	0.38	0.53	0.72				
Robberies, 2008–2013	−0.087	−0.03	0.047	0.03			
Assaults, 2008–2013	−0.079	0.02	0.07	0.05	0.94		
Homicides, 2008–2013	−0.21	−0.13	−0.09	−0.09	0.89	0.94	
HH on public assistance, 2010	−0.21	0.24	−0.09	−0.01	0.65	0.73	0.75
Observations	49	49	49	49	49	49	49

All outcomes are aggregated to the 49 community areas overlapping my sample. Homicides (1870–1930) are cases for which an address could be georeferenced; reported as the count per 1000 residents in 1930. Gangs are also reported as the count per 1000 residents in 1930. Delinquency is the rate of male juvenile delinquency court petitions per 100 males aged 10–16 over the period 1927–1933. Families on relief is reported as the share in 1930. Homicides, robberies, and assaults are rates per 1000 residents over my sample period. Households on public assistance is reported as the share of households. Further details can be found in Section 3.

Table 3
Relationship between modern and historical crime.

	Robbery rate (1)	Assault rate (2)	Robbery rate (3)	Assault rate (4)
Historical homicide rate	−0.000793	−0.000275	−0.000786	−0.000177
	(0.000646)	(0.00249)	(0.000635)	(0.00242)
# of gangs	−0.0300	−0.110	−0.0418	−0.117
	(0.0604)	(0.127)	(0.0613)	(0.126)
Historical zoning controls	N	N	Y	Y
Historical land use controls	Y	Y	Y	Y
Historical demographic controls	Y	Y	Y	Y
Geography controls	Y	Y	Y	Y
Estimation	OLS	OLS	OLS	OLS
Observations	19,159	19,159	19,159	19,159

Columns (1)–(2) report regressions of modern street robbery and assault rates (at the circle level) on historical homicide rates and gangs circa 1923–1926. 10% of observations have a positive historical homicide rate; 24% have a positive number of gangs. These regressions include 1922 land uses, 1920 population and racial composition, and geographic control variables. Sample excludes some observations for which historical land use data is not available due to damaged land use maps. Robust standard errors are reported.

gests that determinants of crime in the 1920s (which may have been related to zoning) have not persisted to the present.

To further validate the exogeneity assumption, I develop a more rigorous test based on historical land use, zoning, and demographics. Essentially, I argue that modern crime in my sample circles should only be related to historical crime to the extent that historical causes of crime have persisted to the present. Such causes include (measurable) land use patterns, zoning, and demographics as well as other (unmeasured) neighborhood characteristics. Thus, if historical crime is independent of modern crime, conditional on historical land use, zoning, and demographics, that strongly suggests that neighborhood characteristics that influenced crime in the past have not persisted.[15]

Following this argument, I test for a relationship between historical and modern crime by regressing modern street robbery and assault rates for my sample circles on historical homicide rates and gangs.[16] I include only those historical homicides that can be geocoded to an exact street address. I also condition on the full set of zoning variables I use as instruments as well as historical land use data and the 1920 population and racial composition. The results are given in Table 3. With either robbery or assault rates as the outcome variable, neither historical homicide rates nor gang presence have any predictive power. This is strong evidence in favor of the exogeneity assumption underlying my instrumental variable strategy.

4.4. Identification: spatial matching

In Section 5.3, I test for the influence of specific commercial land uses (such as bars) on crime. The instrumental variable strategy described above is not applicable here, since historical zoning can only predict general land use patterns and not specific commercial uses. I adopt an alternative approach, matching sample circles whose boundaries lie not more than 200 ft apart. To match circles, I order each observation randomly and identify all of the circles within 200 ft of each observation. Then, proceeding sequentially through the circles, I randomly select one of the neighbors to create a matched pair. In some cases, all of a circle's neighbors are matched to others, so that a circle must be excluded to avoid double-counting. This yields 8704 pairs of observations.[17] Fig. 6 provides an example of matched circle pairs; circles of the same color are paired.

I then analyze differences in crime rates between these matched observations as a function of differences in covariates. Assuming that unobservable neighborhood characteristics vary smoothly across space, they should not differ greatly between

[15] A formal justification for this test can be found in the technical appendix.

[16] I focus on historical homicide rates and gangs since these are the only historical crime outcomes available at a sufficiently fine geographic resolution.

[17] With 8704 pairs, this matching strategy captures 17,408 of my 19,330 observations, with the remaining 10% of observations excluded either because they lacked a neighbor within range or because all potential matches were already paired off.

Fig. 6. Matched circles.

matched observations. While this assumption is not testable, I do find that observable neighborhood characteristics tend to differ little across pairs. The average difference in population between matched observations is 1 person, and the standard deviation of the difference is 181 persons. The average difference in the percentage of residents that are black (Hispanic) between matched observations is 0.03 (0.01) percentage points and the standard deviation of the difference is 4.97 (4.35) percentage points. This is partly a result of aggregation bias since these demographic variables are interpolated from census blocks; however, in general, demographics appear to vary smoothly over adjacent pairs of blocks/block groups.

I estimate models of the form

$$y_i - y_j = \left(x_i - x_j\right)' \beta + \epsilon_{ij}$$

using ordinary least squares. I include all of the covariates from the OLS and IV specifications except community area fixed effects and Walkscores, as the former are unnecessary and the latter exhibit almost no variation over distances that can be traversed by foot in about one minute.

5. Results

I first present descriptive statistics and discuss the spatial pattern of crime in Chicago. I then present results from baseline regressions without instruments in Section 5.1. In Section 5.2, I reestimate these models using historical zoning instruments. In Section 5.3, I use the spatial matching approach to study the role of specific commercial land uses.

Table 4 provides means, standard deviations, and selected quantiles of crime counts and rates in my sample. Street crime in my data is highly concentrated spatially. The median number of street robberies is one and the median number of assaults is two. 42% of observations see no robberies at all over the period 2008–2013; similarly, 22% see no assaults. Sample points with four or more robberies, the top 13%, account for 56% of the 32,252 robberies I observe. This is typical of urban crime and has been well documented in other cities such as Boston, Minneapolis, Seattle, and Tel-Aviv (Sherman et al., 1989; Weisburd et al., 2012; Braga et al., 2010; Weisburd and Amram, 2014).

Commercial use, population density, and Walkscores are the primary predictors of interest in the baseline and instrumental variables analysis. Table 4 provides statistics for these variables. 25% of my sample points contain some commercial use, 11% contain some industrial use, and 48% are strictly residential. The average population in the combined circle-ring area is 857, with an interquartile range of [531, 1105]. The distribution of population is very similar for observations with and without any commercial uses. The average Walkscore is 74.5, which falls into the category of "very walkable."

In the matching analysis, I focus on specific commercial uses. In particular, I examine the effects of restaurants, bars, late-hour bars (those bars permitted to continue serving alcohol past 2 a.m.), and liquor stores. There are 8704 matched pairs of circles in my sample. 21% of these pairs contain at least one restaurant, 5.2% contain at least one bar, and 5.2% contain at least one liquor store. Late-hour bars are considerably less common; only 57 pairs (0.7%) contain at least one.

5.1. Baseline results

Table 5 reports the OLS results for street robbery and assault rates. Identification here relies on a selection-on-observables assumption that the included covariates capture all relevant neighborhood characteristics driving crime. % commercial, ring % commercial, population density, and Walkscores are standardized; thus, the coefficients on the main effects can be interpreted as average marginal effects for those variables. Interpreting the magnitudes of the marginal effects of commercial and ring commercial use requires some attention to the typical variation in these explanatory variables observed in the data. Since the circles are small and capture areas within opposing block faces, they are typically homogeneous, with half of the circles in my sample devoted exclusively to residential use. Circles that contain any commercial use are frequently dominated by such use. The coefficient in the table reflects the differences in outcomes for a standard deviation change in % commercial. However, the comparison between a fully commercial and fully residential circle reflects a 3.5 standard deviation difference in commercial use; this may be a more natural comparison. The variation in ring commercial use is more effectively summarized by its standard deviation.[18]

A standard deviation change in commercial use is associated with a 0.05 standard deviation increase in street robbery and assault rates in the simplest specification (columns (1)–(2)); the shift from a fully residential to fully commercial circle is associated with roughly 1.2 more robberies and 2.5 more assaults per 1000 residents over my sample period. Given that the average robbery and assault rates are 2.6 and 7.3 respectively, this indicates a very strong relationship between crime and land use. Interestingly, the association between population density and street crime rates is negative, contrary to the prevailing wisdom among some sociologists (e.g., Stark (1987)) and perhaps counterintuitive given the fact that denser cities have higher overall crime rates (Haynes, 1973; Glaeser and Sacerdote, 1999). These results are similar across all specifications.

Columns (5)–(6) add an interaction between % commercial and population density. The interaction is of independent interest as it conveys the impact of mixing residential and commercial uses. If the interaction is negative, one could argue that commercial uses in denser areas see less crime than standalone commercial uses. This is what I find across all specifications: While the average commercial relationship is positive, it quickly becomes negative in denser areas. Columns (3)–(4) add Walkscores to the simplest specification, indicating that more walkable areas see higher rates of street crime, especially robberies. This result is magnified in columns (7)–(8), where I include interactions between Walkscores, % commercial, and population density, indication that street rob-

[18] The standard deviation of ring commercial use is 0.15, close to its mean of 0.13, so scaling the average marginal effect by the standard deviation yields an effect similar to that of moving from a fully residential ring to one with the average level of ring commercial use.

Table 4
Descriptive statistics.

Crime:	Mean (Sd)	Q_5	Q_{25}	Q_{50}	Q_{75}	Q_{95}
Robberies	1.7 (3.01)	0	0	1.0	2.0	6.0
Robberies (per 1000 residents)	2.6 (6.93)	0	0	1.0	2.7	9.8
Assaults	5.1 (7.91)	0	1.0	2.0	6.0	19.0
Assaults (per 1000 residents)	7.3 (14.40)	0	0.8	3.0	8.6	26.9
Land use:						
% commercial	0.13 (0.28)	0	0	0	0	0.92
% ring commercial	0.13 (0.15)	0	0	0.07	0.21	0.41
Population density	857 (479.51)	229	531	786	1105	1647
Walkscore	74.5 (10.99)	55.3	68.3	74.4	81.6	92.9
Restaurants	0.33 (1.308)	0	0	0	0	2
Bars	0.03 (0.193)	0	0	0	0	0
Late–hour bars	0.004 (0.08)	0	0	0	0	0
Liquor stores	0.03 (0.209)	0	0	0	0	0
	Observations: 19,330					

Descriptive statistics for crime rates and land use variables. Means with standard deviations in parentheses are presented in the first column, while quantiles of interest are shown in columns 2–6. % commercial is the land cover share within each 150-ft-radius circle. Ring % commercial is the land cover share within a 500-ft ring around each circle. Population density is interpolated from block-level counts to the combined circle-ring area. Walkscore is averaged over each circle. Crimes and specific land uses (restaurants, bars, late-hour bars, and liquor stores) are aggregated to the circle level.

Table 5
OLS results: robberies and assaults per 1000 residents.

Land use	Robbery rate (1)	Assault rate (2)	Robbery rate (3)	Assault rate (4)	Robbery rate (5)	Assault rate (6)	Robbery rate (7)	Assault rate (8)
% commercial	0.0518*** (0.0151)	0.0516*** (0.0147)	0.0510*** (0.0151)	0.0513*** (0.0147)	0.0700*** (0.0160)	0.0668*** (0.0160)	0.0765*** (0.0198)	0.0617*** (0.0164)
Ring % commercial	0.0800*** (0.0193)	0.0802*** (0.0160)	0.0768*** (0.0192)	0.0789*** (0.0160)	0.0724*** (0.0188)	0.0739*** (0.0158)	0.0627*** (0.0172)	0.0703*** (0.0154)
Population density	−0.0716*** (0.0133)	−0.122*** (0.0177)	−0.0735*** (0.0133)	−0.123*** (0.0178)	−0.0412*** (0.0148)	−0.0972*** (0.0159)	−0.0889*** (0.0201)	−0.102*** (0.0191)
Population density × % commercial					−0.113*** (0.0205)	−0.0944*** (0.0166)	−0.110*** (0.0205)	−0.102*** (0.0203)
Walkscore			0.0668*** (0.0195)	0.0285 (0.0196)			0.0856*** (0.0201)	0.0351* (0.0197)
Walkscore × % commercial							−0.0232 (0.0224)	0.0160 (0.0208)
Walkscore × population density							0.0438*** (0.0150)	0.00527 (0.0116)
Land use controls	Y	Y	Y	Y	Y	Y	Y	Y
Demographic controls	Y	Y	Y	Y	Y	Y	Y	Y
Geography controls	Y	Y	Y	Y	Y	Y	Y	Y
Estimation	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Observations	19,330	19,330	19,330	19,330	19,330	19,330	19,330	19,330

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Estimates from OLS regressions of street robbery and assault rates on the full set of land use, demographic, and geographic covariates. Outcome variables are standardized. % commercial, ring % commercial, population density, and Walkscores are standardized; coefficients on main effects can be interpreted as average marginal effects. % commercial is the land cover share within each 150-ft-radius circle. Ring % commercial is the land cover share within a 500-ft ring around each circle. Population density is interpolated from block-level counts to the combined circle-ring area. Walkscore is averaged over each circle. Crimes are aggregated to the circle level. Standard errors are clustered at the police beat level.

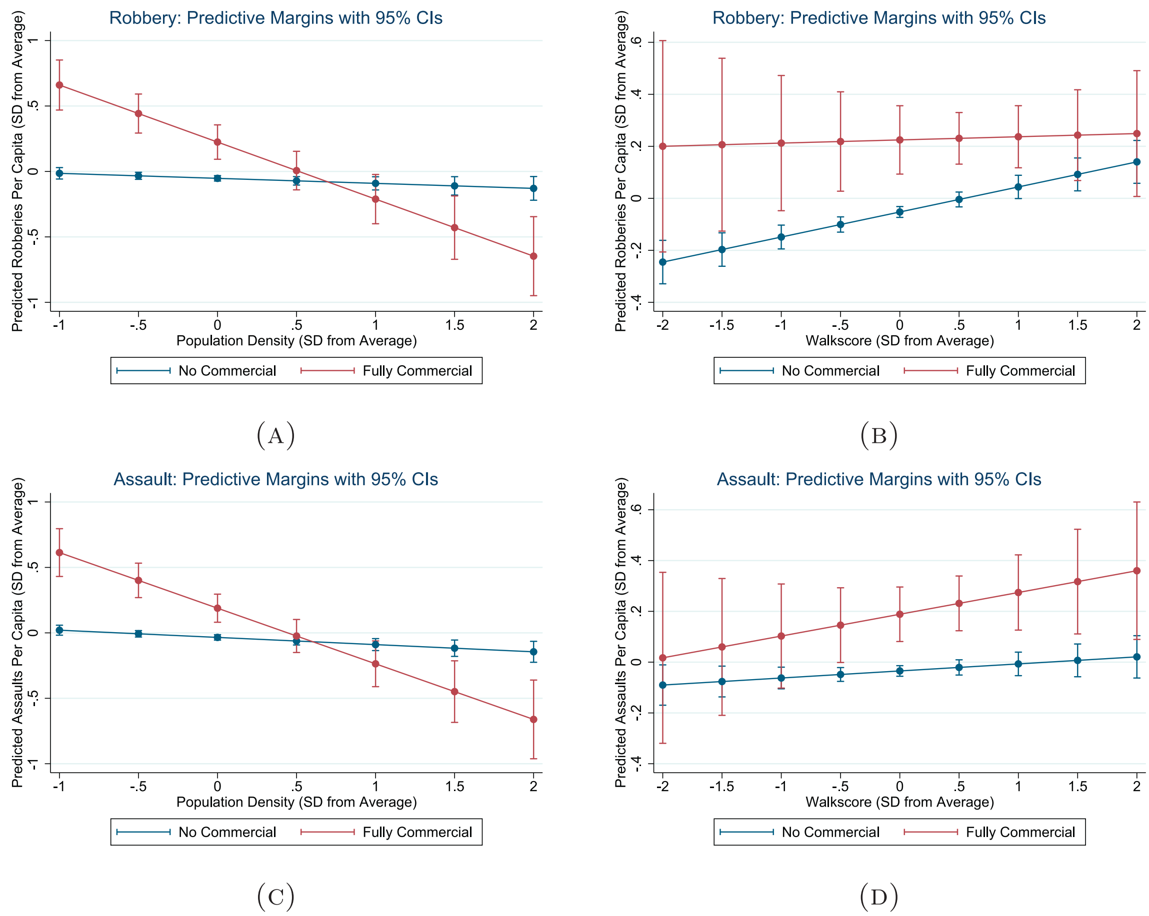


Fig. 7. Heterogeneous impacts of land use on robberies and assaults: OLS regressions. Figures capture variation in the impact of commercial activity on predicted robberies and assaults per capita as a function of population density and Walkscores. Results are from the OLS regressions reported in Table 5. Outcomes and predictors are standardized. Panel (A) shows how the positive impact of commercial activity on robberies declines and reverses sign as population density increases. Panel (B) shows how the impact of commercial activity on robberies shrinks as the Walkscore increases. Panels (C) and (D) repeat this analysis for assaults.

beries in particular are more common in denser, more walkable neighborhoods.

To visualize the heterogeneity in the impact of commercial use, population density, and walkability, Fig. 7 shows how moving from a non-commercial to fully commercial circle varies over the range of population densities and Walkscores observed in the data. In panel A, commercial areas see a half standard deviation higher level of predicted robbery rates over non-commercial areas when population densities are low; in contrast, commercial areas see a half standard deviation lower level of predicted robberies in higher density areas. The results are similar for assaults (panel C). The relationship differs when considering Walkscores: Moving from least to most walkable shrinks the impact of commercial uses for robberies (panel B) but somewhat magnifies it for assaults (panel D).

5.2. IV results

In this section, I reestimate the models from Section 5.1 using two-stage least squares with historical zoning instruments for the endogenous land use variables. The positive average effect of commercial uses is generally of comparable or larger magnitude in the IV models, as seen in Table 6. In contrast to the OLS results, the commercial effect appears to be substantially stronger in more walkable areas, and walkable areas in general see substantially more street crime. The strong negative interaction between population density and commercial uses is still present and larger in magnitude.[19] Population density has a negative impact on crime rates in all specifications, though in general it is not statistically significant. The magnitude of the ring commercial effect is larger in columns (1)–(6), but disappears once walkability and its interactions are taken into account.

Fig. 8 repeats the visualization from Fig. 7 for the IV results. In panel A, commercial areas see a two standard deviation higher level of predicted robbery rates over non-commercial areas when population densities are low; in contrast, commercial areas see a three standard deviation lower level of predicted robberies in higher density areas. The results are similar for assaults (panel C). The relationship is reversed when considering Walkscores: Moving from least to most walkable increases the impact of commercial uses by four standard deviations for both robberies (panel B) and assaults (panel D).

A routine activities interpretation of these findings would suggest that more walkable areas attract more street traffic and thus generate more interactions between potential offenders and victims; this is especially true around commercial areas in walka-

[19] A potential concern is that this negative interaction reflects a local average treatment effect, whereby take-up of high-density, mixed-use zoning is disproportionately concentrated in gentrifying neighborhoods with relatively low crime rates. To test this concern, I replicated the above analysis on two subsamples: Observations where at least 90% of the population is African-American, and observations where at least 25% of the population is below the poverty line, which captures many of the highest crime areas of the city. The results are similar.

Table 6
IV results: robberies and assaults per 1000 residents.

Land use	Robbery rate (1)	Assault rate (2)	Robbery rate (3)	Assault rate (4)	Robbery rate (5)	Assault rate (6)	Robbery rate (7)	Assault rate (8)
% commercial	0.0766*	0.0427	0.0818*	0.0507	0.122***	0.0860**	0.107*	0.0485
	(0.0426)	(0.0408)	(0.0433)	(0.0407)	(0.0458)	(0.0422)	(0.0599)	(0.0548)
Ring % commercial	0.133***	0.138***	0.114***	0.108**	0.111**	0.117***	0.0252	0.0326
	(0.0441)	(0.0422)	(0.0436)	(0.0436)	(0.0451)	(0.0448)	(0.0568)	(0.0566)
Population density	−0.0200	0.00115	−0.0371	−0.0249	−0.0439	−0.0214	−0.319***	−0.161
	(0.0593)	(0.0736)	(0.0597)	(0.0746)	(0.0598)	(0.0749)	(0.111)	(0.121)
Population density × % commercial					−0.135**	−0.127**	−0.444***	−0.370***
					(0.0593)	(0.0620)	(0.137)	(0.135)
Walkscore			0.0933	0.142*			0.353***	0.313***
			(0.0767)	(0.0741)			(0.127)	(0.115)
Walkscore × % commercial							0.213*	0.236**
							(0.115)	(0.109)
Walkscore × population density							0.183**	0.00812
							(0.0888)	(0.0862)
Land use controls	Y	Y	Y	Y	Y	Y	Y	Y
Demographic controls	Y	Y	Y	Y	Y	Y	Y	Y
Geography controls	Y	Y	Y	Y	Y	Y	Y	Y
Estimation	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Observations	19,330	19,330	19,330	19,330	19,330	19,330	19,330	19,330

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$
Estimates from two-stage least squares regressions of street robbery and assault rates on the full set of land use, demographic, and geographic covariates. Outcome variables are standardized. Historical zoning variables are used as instruments for modern land use. % commercial, ring % commercial, population density, and Walkscores are standardized; coefficients on main effects can be interpreted as average marginal effects. % commercial is the land cover share within each 150-ft-radius circle. Ring % commercial is the land cover share within a 500-ft ring around each circle. Population density is interpolated from block-level counts to the combined circle-ring area. Walkscore is averaged over each circle. Crimes are aggregated to the circle level. Standard errors are clustered at the police beat level.

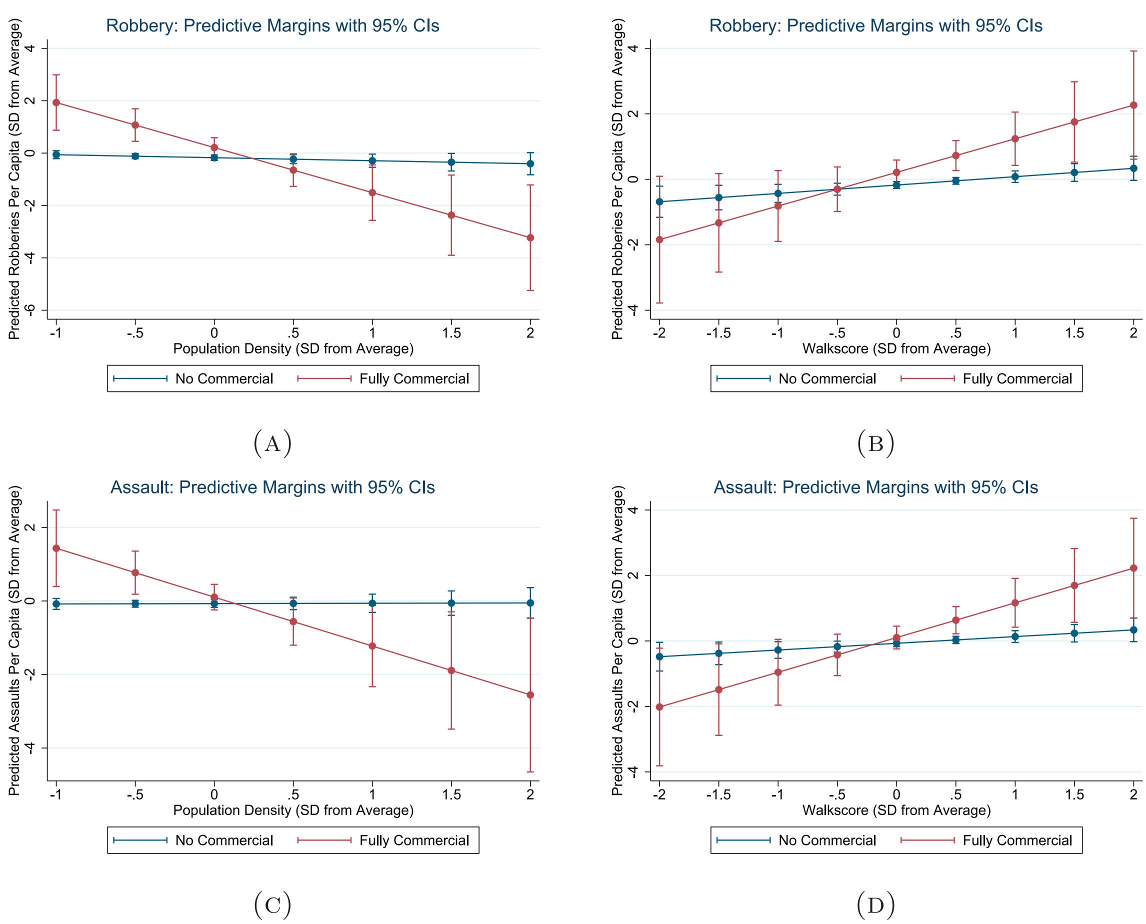


Fig. 8. Heterogeneous impacts of land use on robberies and assaults: IV results. Figures capture variation in the impact of commercial activity on predicted robberies and assaults per capita as a function of population density and Walkscores. Results are from the IV regressions in Table 6. Outcomes and predictors are standardized. Panel (A) shows how the positive impact of commercial activity on robberies declines and reverses sign as population density increases. Panel (B) shows how the negative impact of commercial activity on robberies increases and reverses sign as the Walkscore increases. Panels (C) and (D) repeat this analysis for assaults.

Table 7
Matching results: robberies and assaults per 1000 residents.

Land use	Outcome							
	Robbery rate		Assault rate		Robbery rate	Assault rate	Robbery rate	Assault rate
					(2 a.m.–6 a.m.)	(2 a.m.–6 a.m.)	(6 a.m.–2 a.m.)	(6 a.m.–2 a.m.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% commercial	0.0430*	0.0128	0.0620***	−0.00436	0.0178	−0.00876	0.00995	−0.00170
	(0.0220)	(0.0259)	(0.0193)	(0.0223)	(0.0204)	(0.0236)	(0.0253)	(0.0214)
Ring % commercial	0.0202	0.00374	0.0599***	0.0408**	−0.0120	0.0297	0.00865	0.0416**
	(0.0176)	(0.0204)	(0.0154)	(0.0179)	(0.0219)	(0.0189)	(0.0200)	(0.0184)
Population density	−0.0257	−0.0366	−0.0272	−0.0360	−0.0674	−0.0234	−0.0241	−0.0389
	(0.0377)	(0.0410)	(0.0328)	(0.0348)	(0.0418)	(0.0377)	(0.0410)	(0.0363)
Population density × % commercial	−0.0850***	−0.0988***	−0.0735***	−0.112***	−0.0763***	−0.111***	−0.101***	−0.0976***
	(0.0212)	(0.0227)	(0.0174)	(0.0202)	(0.0192)	(0.0288)	(0.0232)	(0.0192)
# of restaurants		0.0222**		0.0536***	0.0257**	0.0559***	0.0221**	0.0460***
		(0.00885)		(0.0120)	(0.0103)	(0.0179)	(0.00907)	(0.0107)
# of bars		−0.0152		0.0800*	0.112*	0.317***	−0.0458	0.0233
		(0.0338)		(0.0431)	(0.0603)	(0.0775)	(0.0325)	(0.0378)
# of late-hour bars		0.194*		0.787***	0.689***	2.547***	0.0574	0.171*
		(0.108)		(0.171)	(0.209)	(0.792)	(0.128)	(0.0939)
# of liquor stores		0.308***		0.456***	0.214**	0.238***	0.306***	0.461***
		(0.116)		(0.101)	(0.0848)	(0.0709)	(0.114)	(0.102)
Land use controls	Y	Y	Y	Y	Y	Y	Y	Y
Demographic controls	Y	Y	Y	Y	Y	Y	Y	Y
Observations	8704	8704	8704	8704	8704	8704	8704	8704

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Coefficient estimates from linear regressions of standardized differences in street robbery and assault rates (per 1000 residents) across matched pairs of observations, conditional on the full set of land use and demographic covariates differenced across observations. % commercial, ring % commercial, and population density are standardized. Columns (2) and (4)–(8) include 4 additional variables measuring differences in counts of restaurants, bars, late-hour bars, and liquor stores across circles. % commercial is the land cover share within each 150-ft-radius circle. Ring % commercial is the land cover share within a 500-ft ring around each circle. Population density is interpolated from block-level counts to the combined circle-ring area. Walkscore is averaged over each circle. Crimes and specific land uses (restaurants, bars, late-hour bars, and liquor stores) are aggregated to the circle level. Standard errors are clustered at the police beat level.

ble neighborhoods. However, areas with higher residential density benefit from greater monitoring and enforcement of social norms, perhaps due to their correspondingly higher street traffic (generating potential "guardians"). Areas with higher residential density may also see a higher level of pedestrian traffic throughout the day, rather than concentrated during normal business hours; this corresponds to the Jacobs (1961) notion that purely commercial areas will be especially dangerous at night once few pedestrians are on the street.

5.3. Spatial matching results

The IV results establish that commercial uses have a strong effect on robberies and assaults; positive at low densities, negative at higher densities. In this section, I replicate those results using the spatial matching approach. I also use this approach to measure the effects of specific commercial uses such as restaurants, bars, late-hour bars, and liquor stores. This allows me to determine the extent to which the commercial effect is driven by specific uses and how this extent differs across types of crime.

Columns (1) and (3) of Table 7 replicate the basic results from the IV estimation. Commercial uses have a sizable positive effect on crime in their immediate vicinity at low densities but a negative effect at high densities; this is depicted visually in Fig. 9. Columns (2) and (4) add differences in counts of restaurants, bars, late-hour bars (those permitted to stay open past 2 a.m.) and liquor stores across adjoining circles.[20] After accounting for these particular uses, the average effect of general commercial character on robberies and assaults disappears, suggesting that the commercial effect is partly driven by the specific uses accounted for in the model. For both outcomes, magnitude of the commercial/density interaction increases once specific uses are included. Thus, these models reinforce the conclusion from the IV analysis that the general presence of commercial activity results in lower crime rates in denser areas.

The results indicate that restaurants increase robberies and assaults in their immediate vicinity. Bars appear to increase assaults with little impact on robberies. Late-hour bars and liquor stores have a considerably larger effect; an additional late-hour bar yields a 0.19 standard deviation increase in the robbery rate and a 0.79 standard deviation increase the assault rate, while an additional liquor store yields a 0.31 standard deviation increase in the robbery rate and a 0.46 standard deviation increase the assault rate. The fact that liquor stores have a substantially larger impact than the typical bar is surprising given the focus of the criminology literature on the role of bars as crime generators. The large difference in impact between bars that close at 2 a.m. and those that stay open late is also striking. To analyze this further, I replicate columns (2) and (4) restricting the outcomes to street robbery/assault rates between 2 a.m. and 6 a.m. (columns (5)–(6)) and crime rates between 6 a.m. and 2 a.m. (columns (7)–(8)). The results indicate that the late-hour bar effect is largely restricted to after-hours crimes (and considerable larger during these hours); the effect is much smaller outside the 2–6 a.m. window.[21] The impact of bars which close at normal hours appears to also be concentrated in this 2–6 a.m. window. Restaurants and liquor stores appear to attract crime in both time periods, which is unsurprising since many liquor stores and restaurants stay open past 2 a.m. in Chicago.

[20] I do not include any higher order terms for these variables since only a very small fraction of observations have more than a few of each use.

[21] Incidentally, this lends some additional credence to the identifying assumption; if blocks with late-hour bars were systematically different than adjoining blocks without late-hour bars, one might expect to see a difference in crime rates during other parts of the day. Since virtually all other businesses are closed during these late hours, it also appears unlikely that correlated (unmeasured) business types are driving the result.

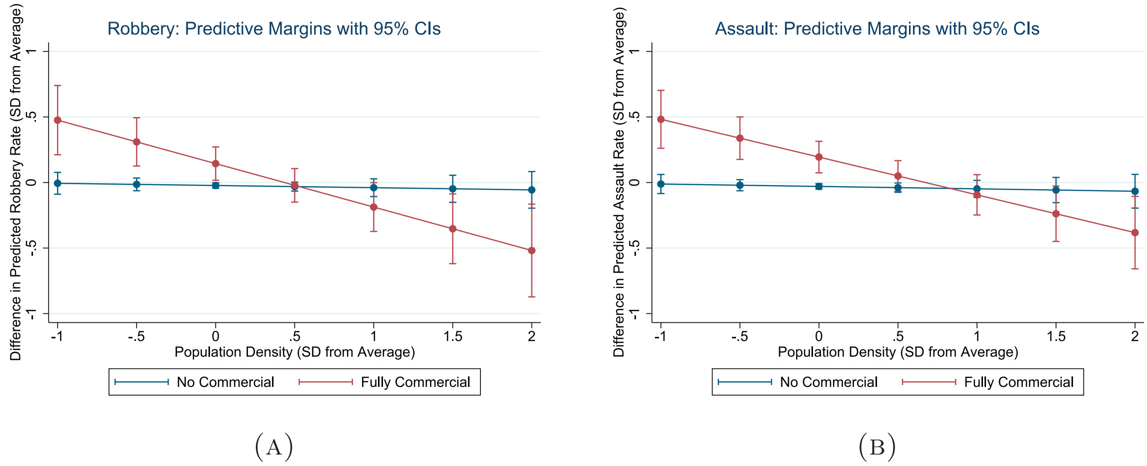


Fig. 9. Heterogeneous impacts of land use on robberies and assaults: matching results. Figures capture variation in the impact of commercial activity on predicted robberies and assaults per capita as a function of population density. Results are from the matching regressions in Table 7. Outcomes and predictors are standardized. Panel (A) shows how the positive impact of commercial activity on robberies (relative to a neighboring circle that may or may not contain commercial activity) declines and reverses sign as population density increases. Panel (B) repeats this analysis for assaults.

It is worth contrasting these results with those of Bernasco and Block (2011). They found a positive relationship between a variety of commercial uses (laundromats, beauty salons, gas stations, etc.) and counts of street crime. However, my analysis suggests that street crime is driven by a small subset of commercial activities. Reestimating these models without matching yields a positive and significant residual average commercial effect; this suggests that the Bernasco and Block results may have been partly driven by unobserved confounders.

6. Discussion and policy implications

My findings indicate that land use is a major determinant of street crime patterns. I show that commercial activity leads to substantially higher street robbery and assault rates, particularly in more walkable neighborhoods. However, this effect decays and then reverses at higher densities, so that dense, mixed-use areas actually exhibit lower crime rates than typical residential areas. Furthermore, crime rates are broadly declining with residential density, a surprising finding given that larger cities are known to have higher crime rates (Haynes, 1973; Glaeser and Sacerdote, 1999). This nonlinear relationship between commercial activity and density is both novel and emerges from all three identification strategies employed in this paper. I interpret this result as a partial vindication of both Jane Jacobs and the routine activities theory: While commercial activity appears to facilitate crime by generating contact between potential offenders and victims, it is possible that a critical mass of pedestrian traffic deters crime. I also find that the positive effect of commercial uses on street crime is driven in large part by liquor stores, restaurants, and bars (particularly late-hour bars). The sizable impact of late-hour bars is almost entirely concentrated between the hours of 2 a.m. and 6 a.m., as is the effect of normal bars. Restaurants and liquor stores appear to drive crime throughout the day.

These findings potentially have important implications for local government policymaking. If high-density mixed-use areas tend to be relatively safe, then zoning which accommodates higher residential density may improve neighborhood safety by generating more street traffic, especially around commercial areas. Zoning which allows for mixed use structures may be preferable to more restrictive rules that aim for solely residential or commercial use. Regulations favoring higher densities also have many other documented benefits, such as lower housing costs, while mixed uses mitigate spatial mismatch between jobs and job seekers (Glaeser and Ward, 2009; Quigley and Raphael, 2005; Gobillon et al., 2007).

Certain policing tactics may also be employed to limit the criminogenic externalities of commercial land use. As discussed previously, crime is highly concentrated spatially, and this concentration is generally stable over time (Weisburd et al., 2012). My results show that a substantial amount of crime in Chicago is concentrated around a narrow subset of bars and focused in a particular window of time. Numerous strategies have been devised which focus police attention on these crime hot spots, including directed patrol and problem-oriented policing. The large empirical literature on this topic convincingly demonstrates that intensive policing applied to crime hot spots can result in sizable reductions in violent street crime without displacing crime to nearby areas (Sherman and Rogan, 1995; Braga et al., 1999; Braga and Bond, 2008). Since zoning is a powerful tool for controlling land use patterns, it could potentially be used to limit the number of particularly criminogenic uses, reducing the strain they impose on police resources.

Future work in this area should further explore the mechanisms through which land use influences crime. As discussed previously, my empirical approach captures both the direct impact of land use on crime and its indirect impacts mediated through changes in policing behavior and neighborhood residential sorting. Data on policing activity and the residential choices of potential offenders could be brought to bear to examine these potential mechanisms. Additionally, future work should address the aggregate implications of land use for neighborhood and city crime levels. The distinction between attracting and generating crime is important here; if commercial uses merely attract a finite local supply of potential offenders, an increase in the amount of commercial activity in an area may affect the spatial distribution of crime but leave the total amount of crime unchanged. Closely related to this is the question of how the extent to which commercial uses are concentrated or diffuse influences the overall crime rate. Jacobs (1961) argues that diffusing commercial uses results in less crime, while criminology research on offender behavior may suggest the opposite (Wright and Decker, 1997; Bernasco and Block, 2009). I am exploring these questions in ongoing research.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jue.2017.05.006.

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