NBER WORKING PAPER SERIES

POLICE OFFICER ASSIGNMENT AND NEIGHBORHOOD CRIME

Bocar Ba
Patrick Bayer
Nayoung Rim
Roman Rivera
Modibo Sidibé

Working Paper 29243
http://www.nber.org/papers/w29243

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2021, Revised May 2022

We thank Nour Abdul-Razzak, Scott Ashworth, Regina Austin, Anjelica Hendricks, Dean Knox, Bob Lalonde, Sera Linardi, Philip McHarris, Jonathan Mummolo, Aurelie Ouss, Canice Prendergast, Quitz´e Valenzuela-Stookey, and seminar participants at Berkeley, Brown, Columbia, Dartmouth, Duke, Florida State, GWU, Northwestern Law, NYU Politics, Stanford, UCL, UCSD Rady, and Yale. We are indebted to Mohammad Abou Harb, Oriana Ballardo, Emma Herman, Kiran Misra, Rachel Ryley, and Yvette Wright for their outstanding contributions to this work. We thank Andrew Fan, Chaclyn Hunt, Maira Khwaja, Sam Stecklow, Trina Reynolds-Tyler, the Invisible Institute, and Craig Futterman for help with the data. We thank UC Irvine Economics, Duke Economics, and Penn Law for generous financial support. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Police Officer Assignment and Neighborhood Crime
Bocar Ba, Patrick Bayer, Nayoung Rim, Roman Rivera, and Modibo Sidibé
NBER Working Paper No. 29243
September 2021, Revised May 2022
JEL No. H4,H72,J3,K4,K42

ABSTRACT

We develop an empirical model of the mechanism used to assign police officers to Chicago districts and examine the efficiency and equity of alternative allocations. Chicago, like most major US cities, uses a bidding process that grants priority based on seniority, resulting in the assignment of the least experienced officers to the most violent and lowest-income neighborhoods. Our empirical model combines estimates of heterogeneous officer preferences underlying the bidding process with causal estimates of officer experience on neighborhood crime and policing. We find that more experienced officers are more effective at deterring violent crime while also being much less likely to use force in comparable policing contexts. We estimate that equalizing officer seniority across districts would reduce Chicago's overall violent crime rate by 4.6 percent and officer use of force by 10 percent. Inequality in crime, and officer use of force across neighborhoods would also decrease sharply. Given officer preferences, we show that this assignment can be achieved in a revenue-neutral way while resulting in small welfare gains for police officers, implying that it is both more equitable and more efficient.

Bocar Ba
Department of Economics
Duke University
213 Social Sciences
Durham, NC 27708
bocar.ba@duke.edu

Patrick Bayer
Department of Economics
Duke University
213 Social Sciences
Durham, NC 27708
and NBER
patrick.bayer@duke.edu

Nayoung Rim
US Naval Academy
Michelson Hall,
Department of Economics
572 Holloway Road
Annapolis, MD 21402
rim@usna.edu

Roman Rivera
Department of Economics
Columbia University
1022 International Affairs Building
420 West 118th Street
New York, NY 10027
United States
rgr2122@columbia.edu

Modibo Sidibé
Department of Economics
Duke University
213 Social Sciences Building
Durham, NC 27708
modibo.sidibe@duke.edu

> One of the challenges for police is that the people dealing with the public are often your most inexperienced workers, the people who have the least experience in policing. It's the person with one, two years on the job who is dealing with the customer.
>
> *Philip Banks III, Former NYPD Chief of Police (The Black and the Blue, pg. 207)*

Introduction

In most major American cities, police officers are assigned to neighborhoods through a bidding process that grants priority based on seniority.[1] If officers prefer to work in safer neighborhoods, such seniority-based mechanisms naturally give rise to an equilibrium in which officers with the least experience patrol the poorest and most dangerous neighborhoods. The purple line in Figure 1 shows how stark this pattern is in Chicago, where, on average, officers with 15-30 years of experience self-select into districts with 35 percent less violent crime than those patrolled by the least experienced officers.

This allocation of police officers to neighborhoods raises several closely-related efficiency and equity concerns, especially if there are substantial returns to experience in policing. In particular, efficiency losses may arise due to the misallocation of the most effective officers to the neighborhoods where they are needed the least. Further, the assignment of less experienced (and less expensive) officers to lower-income, predominantly Black neighborhoods may lead to significant inequities not only related to the effectiveness of policing but also in officer interactions with the community.[2] The green line in Figure 1, in particular, shows how sharply officer use of force declines with experience.[3]

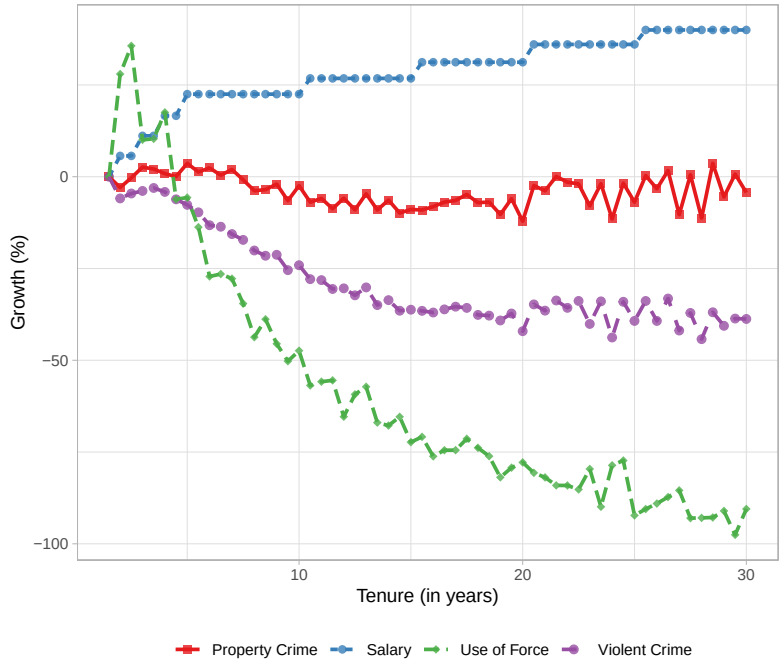
In this paper, we develop an empirical model of the bidding process that assigns police officers to neighborhoods in Chicago and use it to study the economic implications of the current and alternative mechanisms. We use detailed Chicago Police Department (CPD) personnel data from 2007 to 2017, which provides a continuous record of the assignment of officers. The parameter estimates characterize the heterogeneity in police officer preferences for districts, allowing us to predict officer choices under alternative mechanisms and evaluate the associated welfare gains or losses. The results reveal clear officer preferences for districts with lower rates of violent crime, which naturally gives rise to the equilibrium allocation of more experienced officers to safer neighborhoods shown in Figure 1.

[1] In a comprehensive analysis of the collective bargaining agreements governing officer assignment in the 138 largest police departments in the US, we found that 116 explicitly include some form of seniority preference. See this spreadsheet for a full list.

[2] Ba (2018) documents that residents of low-income and predominantly Black neighborhoods are more likely to file formal complaints against the Chicago Police Department both for excessive use of force and for the failure to provide adequate service (e.g., to respond to 911 calls in a prompt manner).

[3] In our empirical analysis, we separate the causal effect of officer seniority on use of force from a component of the observed decline in use of force with officer seniority due to differences in district and beat assignments.

Figure 1: Base Salary, Crime Exposure, and Use of Force by Officer Seniority



Notes: This figure depicts the evolution of base salaries, officer use of force, and average violent and property crime rates in officers' assigned districts in the Chicago Police Department by officer tenure.

The most critical parameters for our analysis are causal estimates of officer seniority on neighborhood crime and police-civilian interactions.[4] In general, more senior officers might use different strategies to deter crime (e.g., build stronger community relations, more accurately identify neighborhood hot spots) and different tactics when engaging with civilians (e.g., less aggressive interactions, less use of force). Estimating the causal impact of officer seniority on crime and civilian interactions requires dealing with the systematic selection of more senior officers into safer neighborhoods. We take three complementary approaches to isolate quasi-experimental variation in the seniority of officers working under the same conditions in the same environment.

First, building off Ba et al. (2021), we perform an individual officer-level analysis using daily data on each officer's assignment, reported arrests, and use of force. For this analysis, we include detailed fixed effects that allow us to compare officers working in almost identical circumstances—the same beat assignment (geographic location and/or task) and shift on the same day of the week in the same month of the same year. This analysis exploits quasi-random variation in who is scheduled to work on, for example, the second Tuesday of the month vs. the third Tuesday of the month. This variation is driven by the CPD's rigid rotational "four-days-on/two-days-off" work calendar, which is set in place at the start of each year. We find that more senior officers make significantly fewer arrests for low-level crimes, such as drug or traffic offenses, and use force much less often. Seniority does not affect property crime arrests, but more experienced officers make fewer violent crime arrests.

[4]For the purposes of our analysis, it does not matter whether the effect of seniority is due to increased experience, age, or a combination of the two. Therefore, we use the terms "seniority" and "experience" interchangeably throughout the paper to refer to the length of time an officer has served in the CPD.

This officer-level analysis allows us to study outcomes linked directly to the officer, such as arrests and use of force. To study the effects of officer seniority on neighborhood crime, we next examine how daily crime outcomes vary with the experience of the officers working in that district on that day. The variation that we exploit for this analysis is again driven by quasi-random variation in the rotational work schedule (aggregating to the district level), and these findings are very similar to the arrest outcomes: more experienced beat officers reduce violent crime while having little or no effect on property crime.

Our third approach examines how monthly district-level crime outcomes vary with the experience distribution of the officers working in the district that month. To deal with the non-random selection of officers into districts, we develop an IV approach that exploits the structure of the seniority-based bidding process directly. In particular, we use the estimated officer assignment model to predict how the composition of each police district would have been expected to evolve over the study period due only to aggregate personnel changes (e.g., retirements) in the Chicago police force. In essence, these simulated instruments eliminate any component of the actual change in a district's officer composition that might have been driven by endogenous officer responses to district-level changes in crime patterns or other factors over the study period. The resulting IV estimates again imply a significant causal impact of officer seniority on neighborhood violent crime, with little impact on property crime.[5] Putting the three analyses together that exploit both within and across districts variations, the results show a clear and consistent pattern: more experienced officers appear to deter violent crime while making fewer low-level arrests and using less force.

With the estimated officer preferences and crime production function in hand, we compare the current allocation of officers in Chicago to counterfactual alternatives. We focus throughout our analysis on revenue-neutral mechanisms that use district-level subsidies to induce more experienced officers to choose districts with higher violent crime rates in equilibrium (relative to the current equilibrium).[6] We show that equalizing officer seniority across districts through this alternative assignment mechanism would reduce the overall violent crime rate in Chicago by 4.6 percent, while also sharply reducing the number of low-level discretionary arrests and instances of use of force by police officers. The allocation of officers under this alternative design is more efficient, as significant reductions in violent crime and use of force are achieved without diverting any additional public resources toward policing and there is a small *increase* in the overall welfare of police officers.[7] This combination of significant reductions in violent crime without an accom-

[5]The IV estimates differ from those estimated using a simple OLS specification in two important ways. First, the overall magnitude of the estimated return to officer experience is much smaller in magnitude—only about 10 percent of simple OLS estimates—in line with the expectation that selection of more senior officers into safer neighborhoods leads to a severe upwards bias in OLS estimates. Second, the results reveal an interesting non-linear relationship between seniority and neighborhood crime, with returns increasing over the first ten years of experience and then remaining largely flat thereafter. This pattern is also reflected in the officer-level arrest and use of force results.

[6]Importantly, while not the main focus of our analysis, equalizing officer experience across districts through the use of district-specific subsidies also results in a better match of officers and civilians on the basis of race and ethnicity. In segregated Black districts, for example, inexperienced white officers are replaced by more senior Black officers in the equitable allocation counterfactual.

[7]Some police officers gain and others lose welfare under the alternative design, but the net effect is negligible because total officer pay is constant. In essence, the new equilibrium simply exchanges pay between officers and officers between districts. As we explain in more detail below, officers actually gain a small amount of welfare, on average, under the equitable assignment mechanism because officers with strong idiosyncratic preferences are better able to satisfy their preferences early in their careers.

panying increase in the number of police officers, more aggressive policing tactics, or additional public funding for the police officers is rare among proposed law enforcement interventions and attractive from a society-wide perspective. This more efficient allocation also has important equity implications: the inequality in exposure to violent crime rates, discretionary arrests, and officer use of force declines across police districts under the alternative assignment mechanism. In particular, the spatial inequality in exposure to crime declines significantly, as violent crime falls sharply in the highest crime and poorest districts.

As far as we know, our paper is the first to examine the economic implications of police officer assignment mechanisms empirically and provide causal estimates of the effect of police officer experience on neighborhood crime, arrests, and use of force. That said, our paper builds directly on three important branches of the literature in economics.

First, the efficiency and equity implications of allocating personnel within political jurisdictions is a general problem in public finance with practical implications for cities and neighborhoods that extend beyond policing. Almost identical issues arise, for example, in studying mechanisms for assigning teachers to schools within public school districts (Hanushek et al., 2004; Boyd et al., 2005; Clotfelter et al., 2006; Jackson, 2009), where recent descriptive evidence documenting within-jurisdiction disparities in personnel and their associated salary discrepancies has prompted a substantial policy debate. More generally, the need to subsidize individuals to select under-served communities is an issue that arises in many settings, including schools, hospitals, the legal system, and other forms of public service. For example, qualified teachers in North Carolina used to receive bonuses of $1,800 for teaching in a set of low-performing and/or high-poverty secondary schools (Clotfelter et al., 2008).[8]

Second, mechanism design has inspired real-world changes in many allocations problems (e.g., FCC spectrum auctions, redesigning the American hospital-intern market). Since the seminal work of Abdulkadiroglu and Sonmez (2003), the empirical mechanism design literature has recently exploded in economics, with applications to school choice, medical school assignments, organ transplantation, and more.[9] Our paper builds on the recent literature developing demand estimation methods in school choice environments (Agarwal and Somaini, 2018; Combe et al., 2018; Fack et al., 2019). We extend this literature to study the assignment of police officers to districts, and in turn, explore how different allocation mechanisms may impact urban crime.

Finally, our paper contributes to the literature on the causal impact of policing on crime. While most of the economics literature has focused on crime responsiveness to the number of police officers (Levitt, 1997; McCrary, 2002; Di Tella and Schargrodsky, 2004; Evans and Owens, 2007; Fu and Wolpin, 2017; Mello, 2019), we study crime response to officers' assignment mechanism holding staffing constant. Hence, our work contributes to the strands of research that focus on the deterrent effect of police deployment and tactics (Eeckhout et al., 2010; Adda et al., 2014; Mastrobuoni, 2020).[10]

[8] Additionally, the "golden handcuffs" program in the UK provides a £10,000 subsidy to teachers who stay in secondary schools in deprived areas, and the "prime REP" program in France offers €3,000 to teachers in deprived areas. As another example, doctors are incentivized to practice in underserved areas in the US using "Health Professional Shortage Area" payment bonuses (see HPSAP program).

[9] See Pathak (2011) and papers therein for a survey.

[10] Chalfin and McCrary (2017) provides an extensive review of the literature on criminal deterrence. Also, see Draca et al. (2011); Blanes i Vidal and Kirchmaier (2017); Weisburd (2019).

We document that experienced officers prevent crime without increasing the intensity of arrests for minor infractions.[11] Finally, by focusing on how officer seniority impacts crime, our paper is closely related to recent research focused on how the composition of the police force affects crimes, arrests, and police-civilian interactions (Donohue and Levitt, 2001; McCrary, 2007; Miller and Segal, 2018; Ba et al., 2021).

The rest of the paper is organized as follows: in Section 1, we present the data and document some key empirical regularities. Section 2 uses the quasi-random variation in officer schedule to quantify the causal effect of tenure on enforcement and deterrence. Section 3 develops the empirical model of assignment, and the estimation strategy is detailed in Section 4. Estimation results are presented in Section 5, and counterfactual analyses are discussed in Section 6. Finally, Section 7 concludes.

1 Crime and Policing in the City of Chicago

1.1 Background

Major metropolitan police departments in the United States, including New York, Chicago, Los Angeles, Houston, Miami, and Philadelphia, assign police officers to districts using a seniority based mechanism. We focus our analysis on the Chicago Police Department for two main reasons. First, we have been able to assemble unusually detailed data on police officers and their assignments to districts, beats, and shifts in Chicago over a long study period, 2007-2017.[12] Second, the mechanism used to assign officers to districts in Chicago is straightforward, well understood by officers, and followed rigorously in practice.

Second, Chicago is a large, racially diverse, and heavily segregated city. The police department is the second-largest in the United States, consisting of more than 10,000 officers. The city is currently divided into 22 geographical police districts managed by commanders who supervise about 65% of the entire CPD.[13] The remaining officers are assigned to specialized units, such as detectives, canine, marine, and helicopter.

1.1.1 Assignment Mechanism

For the first 18 months of their careers, CPD officers start as probationary employees. They are in the police academy for their first six months and then are assigned to and rotate between districts under the supervision of field training officers based on departmental discretion. At the end of the probationary period, new officers are generally assigned to initial districts based on departmental needs and available vacancies.

After the initial assignment, officers can request a transfer from one district to another. CPD directive E04-01-04 specifies the procedures for assignment and personnel transfer. Transfers occur

[11] For more information, see the literature on proactive and disorder policing from Kelling and Wilson (1982) and discussion in Lum and Nagin (2017).

[12] High-quality shift and beat data exist for 2010 through 2017.

[13] Figure B.1 in Appendix B shows the geographical boundaries of the Chicago police districts and characterizes the racial and economic composition of each district based on 2009 boundaries. Prior to 2013, there were 25 districts; three small districts were absorbed into larger ones in 2012, leaving 22.

through a process that allows officers to bid for open positions in other districts. The winning bid goes to the most senior officer. Importantly, this directive also provides detailed instructions that govern how information about vacancies must be made available: on Fridays, in each district, available vacancies are posted on bulletin boards and read-off at roll call by unit commanding officers for three days, ensuring there is no asymmetric information across officers.

1.1.2 Assignment within Districts and Police Activity

Within districts, officers are assigned to beat assignments. Geographically, districts are divided into (usually 3) sectors, which are themselves divided into (usually 3 or 4) beats. On a given day, a subset of officers in a geographic unit are assigned as "beat officers", who comprise around 40% of police officer assignments, and work within a specific geographic beat. These beat officers perform roles that are commonly thought of as policing: they are visible in their squad cars, interact with civilians, and respond to calls for service (usually non-emergency).[14] Other types of beat assignments are desk duty, tactical teams, rapid response, squadron, and school officers. For these, a beat assignment maps to a specific task or role and is not directly tied to a specific geographic beat.[15]

1.2 Data

Our empirical analysis is based on multiple data sources that characterize the composition and assignment of the police force, crime, and officer-civilian interactions in Chicago. Appendix A.1 provides a detailed description of the data sources. Our main dataset consists of all available officers from 2007 to 2017, and includes demographic information (race, gender, and birth year), appointment date, unit assignment, and salary. In addition, daily shift and beat assignment histories, arrests, and incidents of use of force are available from 2010 to 2017.[16] For the portion of our analysis based on daily officer-level data, our final sample includes 7 million officer-day observations for almost 10,000 unique officers. These data detail the starting and ending times of the officer's shift on a given day, whether they were present, and their beat assignment (an assignment code which relates to a geographic location or task/role).

We supplement our Chicago police personnel dataset with crime data at the beat and district levels. The primary outcomes for our district-level analysis are the monthly district crime rates, which we compute as the number of crimes in a month-year per 1,000 residents. We distinguish between violent and property offenses starting with the standard FBI classifications and then add additional crimes not tracked by the FBI during our period of study. In this study, violent offenses include murder, manslaughter, rape, assault and battery (aggravated and simple), and robbery; property crimes include burglary, arson, larceny (theft), motor vehicle theft, and other property-related crimes. Detailed information about crime data is provided in Appendix A.4, while Figure

[14] Rapid response officers, about 7% of assignments, work in districts as well and generally respond to emergency calls for service and supporting beat officers.

[15] See https://home.chicagopolice.org/community-policing-group/how-caps-works/beat-officers/ and https://home.chicagopolice.org/community-policing-group/how-caps-works/rapid-response-officers/ for more information.

[16] The precise steps to derive our final sample are provided in Appendix A.2 and A.3.

B.2 in Appendix B documents the geographic distribution of crime in the city of Chicago.

1.3 Descriptive Patterns

In Appendix C, we document three salient facts about crime and policing in Chicago over our study period: i) the size of the police force declined at just under one percent per year, ii) the police force grew consistently older, and iii) crime rates declined sharply, with the largest drops in neighborhoods with initially higher levels of violent crime.[17] In the rest of this section, we document several important aspects of officer mobility that inform our analysis.

1.3.1 Choices and Matching Patterns

The key empirical regularity that motivates our analysis is the systematic sorting of more senior officers into neighborhoods with lower violent crime rates, as shown for the police force as a whole in Figure 1 in the introduction. Figure 2 displays scatter plots of the per capita violent and property crime rates in districts in which Black, white, and Hispanic officers work by tenure. Black officers tend to work in higher crime districts, both property and violent, over their entire careers relative to hispanic and white officers. Nevertheless, all officers see declines in violent crime rates in the districts in which they work as their tenure increases. This is due primarily to the fact that officers start their careers working in districts with relatively high violent crime rates and gradually move to districts with less violent crime as they gain experience and more discretion over where they work.[18] However, the decline in violent crime rates is significantly larger for white and Hispanic officers relative to Black officers. Table 7 in the appendix shows the characteristics of districts before and after a move.

1.3.2 Career Transitions

Our analysis focuses on the way patrol officers are assigned to neighborhood districts. This section describes several key patterns related to the career dynamics of patrol officers. We begin by characterizing the ways that officers can exit the sample: (i) by being promoted to detective or sergeant, (ii) by joining a specialized unit, or (iii) by leaving the Chicago Police Department. Figure 3 displays the cumulative hazard rates by officer tenure for (i) promotion to sergeant, (ii) promotion to detective, and (iii) exit, meaning retirement, termination, or other exit from the CPD.

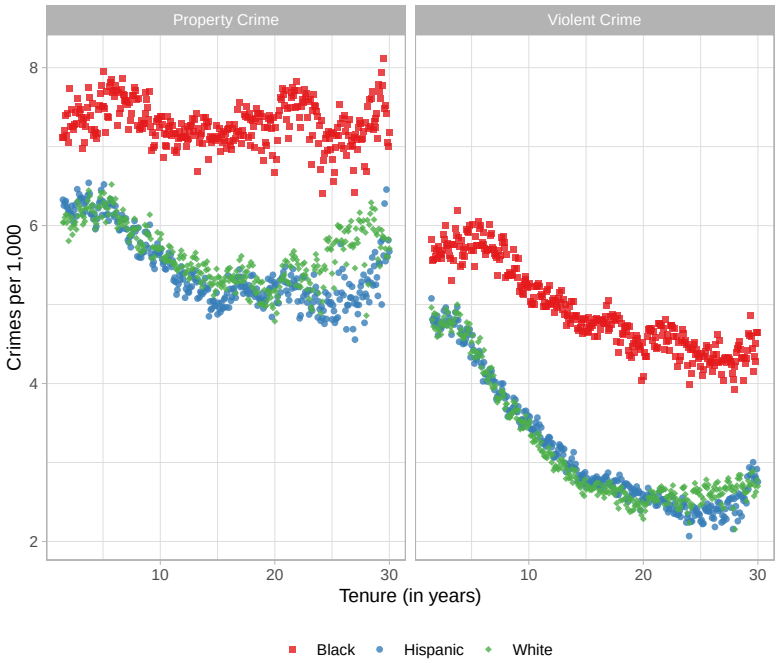
The annual hazard rates for all of these career transitions are very low. Less than 10% of officers have been promoted to sergeant or detective after 20 years of service. And only about 10% of officers exit the CPD before 20 years of experience. At 20 years of tenure, the slope of the exit rate begins to increase sharply as officers move to the highest tier of retirement benefit replacement rate and begin to retire. Since salary and other benefits max out after 30 years of service, many officers continue to work up to 30 years.[19]

[17] It is worth noting that while the violent crime rate fell more in districts with initially high rates, the relative ranking of districts by the violent crime rate is essentially constant over the full study period.

[18] The combination of the increase in average officer experience level and the fall in violent crime rates over our study period also contributes a small amount to this observed pattern.

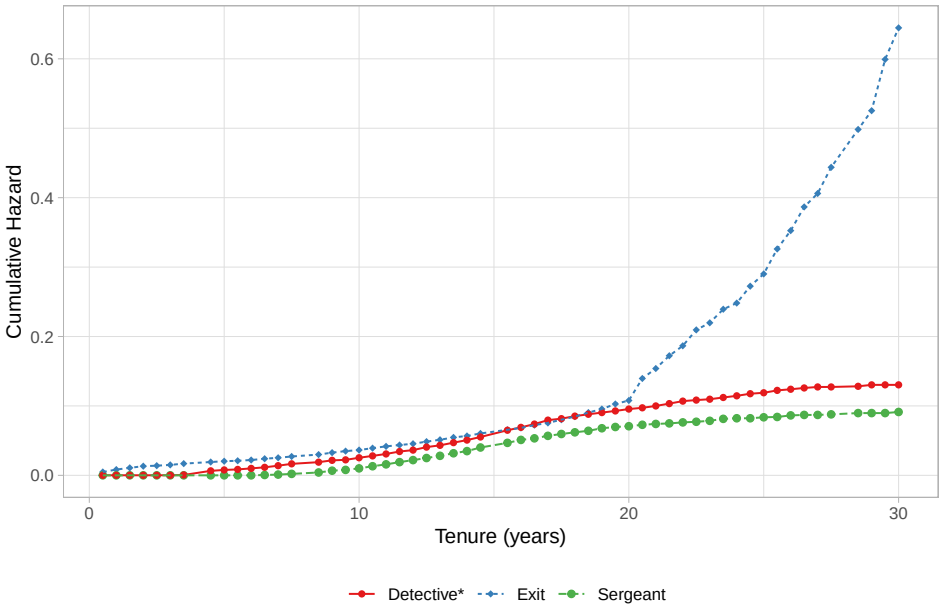
[19] See https://chipabf.org/members/ for more details on retirement tiers for CPD officers. We attempted to use the

Figure 2: District Crime Exposure by Officer Seniority and Race



Notes: These figures displays scatter plots of the per capita crime rates of assigned districts by officer race and tenure. The figure on the left depicts property crime rates, and the figure on the right depicts violent crime rates.

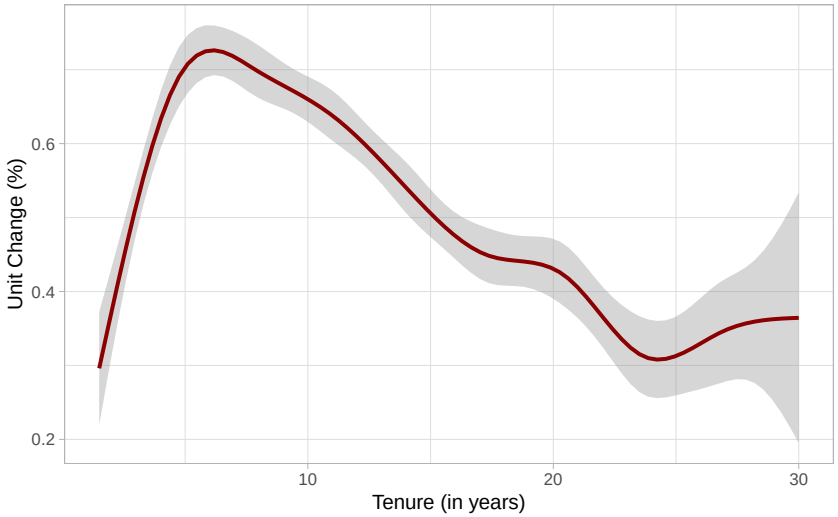
Figure 3: Cumulative Promotions and Exits by Officer Seniority



Notes: This figure depicts the cumulative hazard rate for promotion to sergeant, promotion to detective, and exit/retirement from the department.

We next document the rate at which patrol officers move between districts. Figure 4 plots the monthly average transition rates to another district by officers' tenure. Overall, there is an inverse U-shape between seniority and the rate of transition. The transition rate increases sharply during the first six years of tenure, peaking at a monthly rate of just over 0.7 percent. The transition rate then declines for the remainder of officers' careers. This dynamic pattern of moves is consistent with a seniority-based assignment mechanism that makes it difficult to move at the very beginning of the career and leaves little reason for late-career transitions once the majority of senior officers have been able to sort into their preferred locations.

Figure 4: District Mobility Rates by Officer Seniority



Notes: This figure plots the monthly average district transfer rate by officer tenure. The solid line was estimated using a LOESS regression. The shaded gray areas represent 95% confidence intervals.

Table 8 in Appendix D summarizes the total number of district moves we observe for the set of patrol officers we see at any point in the sample. About two-thirds of our sample do not change districts during the study period, due in part to the fact that some officers only enter (exit) the sample late (early) in the study period. Male and white officers are slightly more likely to change districts at least once. Overall, 21% of officers move once, 7% move twice, and only 4% of the sample change districts more than twice.

2 Effect of Officer Experience on Policing Outcomes

Police officers fulfill multiple functions in our society, including not only identifying and capturing offenders but also deterring individuals from participating in illegal activities in the first place. Police officers also hold a great deal of power and have considerable discretion over how they carry out these functions and interact with the public. In estimating the causal effect of officer seniority on crime and civilian interactions, our main goal is to identify differences in the ways that senior

20-year kink in retirement propensity as an instrument for average unit tenure. However, given that there is no significant level shift and only a change in slope, this proved to be a very weak instrument in our application.

and junior officers engage in policing and the impact that this has on the community.

In general, identifying the effect of seniority is challenging because of the potential selection of experienced officers into safer districts, as documented in Figure 2, and the potential for officers to be non-randomly assigned to heterogeneous beats and shifts within a district. In this section, we present two analyses that exploit day-to-day variation in assigned officers to identify causal effects of officer seniority on arrests, use of force, and crime. This section proceeds in three steps. First, we describe a source of quasi-random variation in officer assignment that allows us to mitigate several potential sources of selection. Then, we analyze the effect of tenure on the enforcement decision of officers using the most detailed data available on arrests and use of force at the officer level. Finally, we study the effect of officer seniority on crime using daily violent and property crime data matched to each district.

2.1 Quasi-Random Variation in Officer Daily Assignment

The analysis presented in this section exploits variation in the composition of officers working on the same day of the week within the same month (e.g., variation across the Tuesdays in February 2010), as in Ba et al. (2021) and Rivera (2022). The rigid rotational structure of the CPD operations calendar ensures that the set of officers who are scheduled to work on a specific day is as good as randomly assigned. Within a unit, an individual officer's rotation is determined by a bidding process before the beginning of each calendar year, after which they are assigned to a specific watch/shift and their day off group (DOG), which also determines how long their regular shifts are. The most common type of rotation in our data is the 4-2 rotation which map to 8.5 and 9 hour shifts (depending on the year), meaning the officer works 4 days in a row "on" and 2 days in a row "off". This also means that the days of a week (e.g., Sunday, Monday, Tuesday) that each officer is working will differ from week to week.[20] In this way, the CPD calendar structure ensures that officers cannot generally choose which specific days they will work and that the composition of officers is uncorrelated with the days of the week.

The key implication of the rotational structure is that the probability of working on a specific day is unrelated to the tenure of the officer conditional on the watch and rotation an officer is assigned to for that year. Table 1 reports estimates for three specific days taken at random Monday, Wednesday and Friday.

[20]Other rotations include 8 hour and 10/10.5 hour rotations which follow slightly different patterns (such as involving extra days off around weekends) and are far less common, though crucially, all schedules are fixed and determined in advance by the annual operations calendar. Figure F.1 in the appendix displays the schedule for 2015. For example, according to the calendar, DOGs 65 and 66 (bottom left, corresponding to 8.5 hour 4-2 DOGs) are off on January 1st, then DOGs 66 and 61 are off on January 2nd, and DOGs 61 and 62 are off on January 3rd.

Table 1: Testing for the Quasi-Random Variation

	Monday	Wednesday	Saturday
Tenure = [5,10)	0.000387	-0.000483	-0.001495
	(0.000505)	(0.000376)	(0.000737)
Tenure = [10,15)	0.001315	-0.000325	-0.001417
	(0.000761)	(0.000471)	(0.000834)
Tenure = [15,20)	0.001789	-0.000609	-0.001999
	(0.001686)	(0.00031)	(0.001467)
Tenure = 20+	-0.000243	0.000661	0.001263
	(0.002259)	(0.00075)	(0.001914)
Mean DV	0.144855	0.147178	0.124944
Number of Observations	7409284	7409284	7409284

Notes: This table displays the effect of officer tenure on the probability of working a specific day. All estimates control for officer watch and shift length. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.

All coefficients in 1 are precisely estimated to be zeros. Appendix F provides additional information and tests. Overall, the data are consistent with the CPD's official assignment calendar. As a consequence, by isolating variation across the same days of the week in the same month, we can compare officers working in the same place, role, and time and, importantly, with the same opportunity to take enforcement action.

2.2 Effect of Officer Seniority on Enforcement

Our first analysis focuses on the effect of tenure on the enforcement decisions of officers working the same beat and shift on the same day of the week within the same month.[21] For expositional simplicity, we refer to the fully interacted Month-Year (M) $\times$ Day-of-Week (D) $\times$ Shift (S) $\times$ Beat (B) fixed effects with the acronym *MDSB*. Our estimating equation relates each outcome Y_{ijt} for officer i assigned to MDSB j on day t to individual officer fixed effects α_i,[22] MDSB fixed effects γ_j, and a flexible function of officer experience τ_{it}:

$$Y_{ijt} = \alpha_i + \gamma_j + \beta\tau_{it} + \epsilon_{ijt}\,. \tag{1}$$

where τ_{it} is the tenure of the officer i at time t. In practice, we break the tenure variable into one-

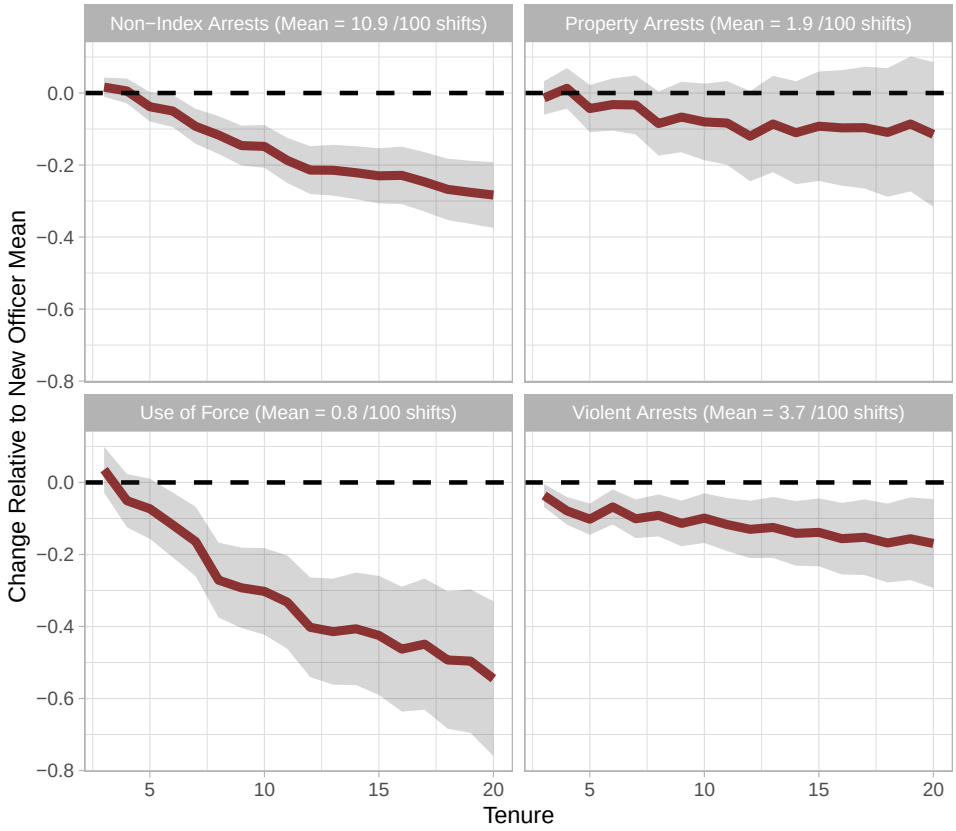
[21]This analysis is based on a subset of the full set of officers described in Section 1. In particular, we consider the daily assignments of all patrol officers working in watches 1-4 (i.e. morning, afternoon, night, and specialized shifts) between 2010 and 2017 in the geographic units. The resulting daily panel contains over 8 million officer-day observations on almost 10,000 officers, which is about 78% of officers in the primary analyses. These data are also supplemented with records on adult arrests. An arrest is counted only for officers listed as primary or secondary officers on the arrest and not for assisting officers.

[22]The inclusion of officer fixed effects implicitly controls for an officer's starting age. So while an additional year of tenure means an officer is one year older, using individual fixed effects means we can compare officers who are, for example, 45 at 20 years of tenure to those that are 55 at 20 years of tenure.

year bins. The reference category is non-probationary officers (more than one and a half years of experience) with less than three years of experience ("new officers"), meaning all estimated effects are the impact of more senior officers relative to the average outcomes for new officers.

The inclusion of MDSB fixed effects allows for comparisons of officers essentially working in the same place/role and time and, notably, with the same opportunity to take enforcement action. The outcomes of interest are violent, property, non-index crime arrests and officer use of force.[23] Non-index crimes, which are often referred to as "victimless" offenses, tend to be misdemeanors or violations of special laws (e.g., traffic violations, drug, municipal code violations), and as such, are more sensitive to officers' enforcement discretion (Lum and Nagin, 2017). Violent and property crime arrests made by officers, in contrast, are typically made as part of an immediate response to an offense with an identifiable victim and, as such, are generally less discretionary.

Figure 5: Effect of Officer Seniority on Arrests and Use of Force



Notes: These figures depict average within-MDSB differences in arrests and use of force by officer tenure after controlling for officer fixed effects. MDSB is a unique combination of month-year, day of the week, shift time, and assigned beat. Gray shaded areas depict 95% confidence intervals.

For every 100 shifts, officers with less than three years of experience make about 3.7 violent,

[23] Violent and property crime categories include official index crimes and related non-index crimes. For example, index violent and property crimes include murder, robbery, motor vehicle theft, and burglary, while non-index violent and property crimes include domestic violence, simple battery and assault, manslaughter, fraud, and vandalism. We define non-index refers to all other non-index crimes. See Section A.4 for more details.

1.9 property, 10.9 non-index arrests and report using force about 0.8 times. Relative to these least experienced officers, our findings imply that arrests and use of force decline sharply with officer experience over their first 10 years and more gradually between 10 and 20 years. There is a negligible and imprecise effect of experience on property crime arrests and a relatively minor effect on violent crime arrests (a decline of about 0.5 arrests per 100 shifts). The most important dimensions of differentiation between officers of different seniority levels are related to arrests for non-index crimes and use of force, with declines of about 20% and 30% within the first 10 years and up to 30% and 50% at 20 years, respectively, relative to the mean of new officers. Taken as a whole, the results presented in Figure 5 imply that officers significantly change the way that they perform their duties and interact with civilians as they gain more experience, in a manner that suggests less discretionary and aggressive interactions with civilians.

2.3 Effect of Beat Officer Seniority on Crime

While quantitatively important, the economic significance of arrests for violent and property crime may be relatively limited in practice. Beat officers (as opposed to detectives) do not usually work to 'solve' past crimes but instead focus on crime prevention, active deterrence, engagement, and enforcement. In fact, most crimes with victims (violent and property) are never cleared with an arrest. In Chicago, the majority of violent crimes are not cleared (e.g., only 37% of aggravated assaults), and the vast majority of property crimes are not cleared (less than 15% of all index property crimes), see the CPD's 2017 annual report for more details.[24] The key implication is that the incapacitation of potential offenders through arrests for past offenses is relatively rare and not necessarily socially desirable: an arrest means the crime has already occurred. Instead, crime reduction mechanisms are generally divided between deterrence –would-be criminals choose not to commit a crime due to increased likelihood of detection or punishment – and incapacitation – would-be criminals are incapable of committing a crime due to being in custody. Existing research indicates that deterrence is the one of the main mechanisms through which police forces reduce crime (Chalfin and McCrary, 2017). Notably, it is well-documented that violent crime is more responsive to deterrence (e.g., police presence/manpower) than property crime.

To estimate the relationship between tenure and crime, we again exploit the quasi-random variation provided by the CPD's rotational calendar to examine how violent and property crime varies with the tenure profile of the beat officers working in a district on a given day. In particular, our estimating equation relates crime c in-district d on day t to the tenure distribution τ_{dt} of the beat officers assigned to work on that day:

$$c_{dt} = \beta\tau_{dt} + \gamma Z_{dt} + \rho_{MDD(d,t)} + \varepsilon_{dt}. \quad (2)$$

Additional controls, Z_{jt}, include the total number of officers and shares of Black, Hispanic, and female officers working in the district that day. We break the tenure variable into 5-year bins. The reference category is officers with less than five years of experience, i.e., "new officers", meaning all

[24]Chicago is not an outlier - according to data from the FBI in 2017, less than 50% of violent crimes and less than 20% of property crimes were cleared by an arrest.

estimated effects are the impact of more senior officers relative to mean outcomes for new officers.[25] Similar to the officer-level analysis, we control for month-year by day-of-week by district (MDD) fixed effects, $\rho_{MDD(d,t)}$, so that the variation in officer tenure is derived from which officers work on, for example, the first versus second Thursday of a given month-year (e.g., January 2011) in a given district. Standard errors are clustered at the MDD level.

Table 2: Effect of Beat Officer Seniority on Crime

	Violent Crimes			Property Crimes		
	(1)	(2)	(3)	(4)	(5)	(6)
Share Tenure = [5,10)	-1.345***	0.663***	-1.094**	10.201***	-6.509***	-0.613
	(0.159)	(0.229)	(0.478)	(0.222)	(0.474)	(0.601)
Share Tenure = [10,15)	-14.617***	-4.945***	-1.103**	6.289***	-5.078***	-0.956
	(0.166)	(0.301)	(0.464)	(0.268)	(0.503)	(0.614)
Share Tenure = [15,20)	-15.666***	-4.106***	-1.305**	-0.716**	-2.755***	0.745
	(0.199)	(0.288)	(0.523)	(0.281)	(0.667)	(0.747)
Share Tenure = 20+	-10.946***	-2.86***	-1.07*	-1.974***	0.045***	2.342**
	(0.278)	(0.378)	(0.649)	(0.336)	(0.003)	(0.971)
Mean DV	10.516	10.516	10.516	17.786	17.786	17.786
Number of Observations	66745	66745	66745	66745	66745	66745
Controls	X	X	X	X	X	X
Districts (D)		X			X	
Month-Year-Day-District (MDD)			X			X

Notes: This table displays the effect of beat officer tenure on the number of violent (Columns (1)-(3)) and property crimes (Columns (4)-(6)) reported on a day within a geographic district. Tenure shares are computed as the share of beat officers (relief and non-relief) who reported working in a given unit on that day at any time. The excluded group is the share of officers with less than 5 years of experience, and probationary officers (less than 1.5 years) are excluded from the data. Controls include the number of beat officers and the shares of Black, Hispanic, and female beat officers. Day fixed effects refer to the day of the week. Standard errors clustered at the MDD level are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.

Estimates are presented in Table 2. The first three columns of the table report results for violent crime. Column (1) includes only controls for other officer characteristics, while Column (2) adds district fixed effects and Column (3) adds the fully interacted MDD fixed effects - i.e., month-year by day-of-week by district. Columns (4)-(6) show comparable specifications for property crime.

The specifications shown in Columns (3) and (6) are our main results for violent and property crime, respectively. The coefficients measure the change in the number of crimes in a district on a given day resulting from an increase in the share of officers in a given tenure bin relative to those with less than 5 years of experience. Focusing on Column (3) for violent crime, replacing 10 percent of a district's least experienced officers on a given day with a comparable number of officers who have 10-15 years of experience would reduce the number of violent crimes in that district by 0.11, or a little more than 1 percentage point relative to the mean. These estimates for violent crime reductions are similar in magnitude to the reduction in violent crime arrests in the officer-level analysis reported in Figure 5.[26] There also appears to be a non-linear effect of tenure on violent

[25] Again, we exclude probationary officers from our sample.

[26] In Appendix G, we investigate the possibility that the returns to experience might vary with whether an individual

crime: relative to new officers (less than 5 years), beat officers with higher tenures significantly reduce violent crime, though the additional effect of more experience (e.g., moving from 10-15 to 15-20 years) is small relative to the $<$ 5 to 10-15 difference. The results presented in Column (6) for property crime are generally smaller in magnitude, statistically less precise, and show no clear monotonic pattern.

Comparing the results across Columns (1)-(3) illustrates the importance of controlling for the systematic selection of senior officers into districts with lower violent crime rates. In particular, naively examining the correlation of officer seniority and violent crime without any controls for district fixed effects, as in the specification shown in Column (1), would overstate the effects of officer seniority on violent crime by 8-10 fold. Interestingly, including only district fixed effects, as shown in Column (2), would reduce this bias but still yield a substantially overstated effect size relative to including district by year-month by day-of-week fixed effects. This suggests that officer selection into districts likely responds to changing crime rates and other conditions over the study period.

Overall, we view the results presented in these first two analyses based on daily variation in officer assignment as indicating that experienced officers are more effective at preventing violent crimes by deterring them (and, therefore, making fewer violent crime arrests). They also appear use of force far less often and reduce pro-active (low-level) arrests. As a consequence, arrests may be a misleading measure of police productivity (Mas, 2006; Prendergast, 2021), in line with Lum and Nagin (2017), who state that "arrests also signify a failure of prevention; if crimes are prevented in the first place, so are arrests and all of the ensuing costs of punishment".

Having shown that experienced police officers more effectively deter violent crime, we now consider whether incentive-compatible matching mechanisms can be developed, which would induce their mobility to the districts where they are needed the most. Doing so requires working at the district level, where the main assignment mechanism operates.

3 An Empirical Model of Police Assignment and Crime

In this section, we construct and estimate a model of the mobility of police officers across districts, as governed by the seniority-based bidding process. We use the model to quantify officer preferences for working in various geographical districts across the city as a function of the composition of the community and crime rates. We then estimate neighborhood crime production functions using a simulated IV strategy based on predicting how the officer tenure distribution of each district would have been expected to evolve over the study period due only to aggregate personnel changes (e.g., officer retirements).

3.1 Basic definitions

Consider a problem in which a finite set of officers $\mathcal{I} = \{1, \ldots, I\}$ are to be assigned to a set of districts $\mathcal{D} = \{1, \ldots, D\}$. Police officers are heterogeneous according to ϑ, which captures officer

officer was initially assigned to a high-crime district. While the results are somewhat noisy, they imply that, if anything, initial assignment to a high-crime district is associated with lower returns to experience in deterring violent crime.

attributes (e.g., age, gender, race, education), preferences, and work experience. Two aspects of ϑ are especially important for our analysis: (i) officer preferences for working in districts with different characteristics such as crime rates, location, and racial composition, which we denote by v, and (ii) an officer's tenure with the Chicago Police Department, τ, which affects priorities for district assignments. Let Θ denote all officer types ϑ. An officer i has a strict preference relation $\succ_i$ over the set of districts and being outside of the police force (denoted by $\emptyset$). We write $\mathrm{d} \succ_i \mathrm{d}'$ if officer i prefers district d to district d′.

Police districts are endowed with strictly positive and exogenous size (i.e., number of assigned officers) $Q = (Q_1, \ldots, Q_D)$. Each district d has a strict preference relation $\succ_\mathrm{d}$ over officers. While police districts in Chicago do not play an active role in the bidding mechanism, the district's preference relation can be used to model the priorities built into the mechanism.

Matching We consider the matching between officers and districts. Formally, a matching is defined as follows:

Definition 1. *A **matching** μ is a mapping from $\mathcal{I}$ into $\mathcal{D} \cup \{\emptyset\}$ such that (i) $\mu(\vartheta) \in \mathcal{D} \cup \{\Theta\}$ ii) $\mathrm{d} \in \mathcal{D}$, $\mu_\mathrm{d}(\vartheta) \subseteq \Theta$ is countable, and $\mu_\mathrm{d}(\vartheta) \leq Q_d$ and iii) $\mathrm{d} = \mu(\vartheta)$ iff $\vartheta \in \mu(\mathrm{d})$.*

Part (i) of the definition states that each police officer is matched to a district or to the outside option. Part (ii) ensures that the number of police officers in a district $\mu_\mathrm{d}(\cdot)$ can not exceed its size. Finally, part (iii) is a consistency condition, requiring that an officer is matched to a district only if the district is matched to the officer.

This definition of matching is similar to the standard college admission problem and many other two-sided matching problems in the literature. The interesting economic patterns are driven by the rules governing the reallocation of officers, which continuously reassign existing and new officers to vacancies. This reassignment process requires two key inputs: (i) the dynamics of vacancies and (ii) priorities built into the district preference relation.

Vacancies Vacancies can open in a district in each period for three reasons: (i) an existing patrol officer leaves due to retirement, exit, promotion, or move to specialty unit, (ii) an existing patrol officer transfers to another district, or (iii) the CPD changes the number of officers assigned to the district, Q_d. Formally, the number of vacancies in district d is denoted by $\mathcal{V}_\mathrm{d} = ||\emptyset||$. Vacancies that stem from retirements are likely to be filled by younger officers eager to move to a more desirable district. Positions vacated when patrol officers transfer to another district are sometimes less desirable. Any unwanted positions are ultimately assigned to new officers as their initial placement following their probationary periods.

Priorities For Chicago's current mechanism, the priorities determining patrol officer district assignment can be summarized as: (i) prefer any officer who worked in the district in the prior period to any officer who worked elsewhere, then (ii) prefer an officer with more seniority to one with less. Formally, this can be written as:

Definition 2. *The Chicago bidding mechanism is characterized by the district preference relation, $\succ_d$, as follows. If an officer i is assigned to district d in period $t-1$, while officer i' is not, then $i \succ_d i'$ even if $\tau_i < \tau_{i'}$. Otherwise, $i \succ_d i'$ iff $\tau_i > \tau_{i'}$.*

While priorities are defined by seniority, prior assignment trumps priorities when it comes to filling positions. This is in contrast with many assignment mechanisms, where tenured civil servants may claim the position of an untenured agent. Because almost all officers are initially assigned to districts based on need, sorting emerges in the Chicago mechanism over time, as officers gain experience and can better actualize their preferences. We can express this sorting property in the form of a proposition. In particular, let $\mathbf{m}_\mu$ denote a set of moments characterizing the matching μ.

Proposition 1. ***Sorting***
Assume there exists a set of district characteristics $\boldsymbol{c}_d$ such that

$$d \succ d' \quad \forall \quad \boldsymbol{c}_d \gtrless \boldsymbol{c}_{d'} \,. \tag{3}$$

Assume $\mathcal{V}_d > 0$; then, any matching μ implies

$$\boldsymbol{m}_\mu(d) \gtrless \boldsymbol{m}_\mu(d') \,. \tag{4}$$

This sorting result is general and applies in many different contexts, such as the allocation of teachers to schools. Its generality does not hinge on the specific allocation mechanism considered here but simply on the dynamic property of the allocation. A constructive proof of proposition 1 is as follows. For simplicity assume preferences are unidimensional, given by $\grave{v}e_d = \alpha - \boldsymbol{c}_d$. Consider an initial allocation where officers are randomly assigned to districts. As vacancies open up, senior officers who were randomly assigned to high crime districts move to lower crime districts and are replaced by new officers. As time progresses and more vacancies open, the matching gets less uniform, as the senior officers get reassigned to lower crime districts. The ensuing sorting is a byproduct of the choice-based mechanism, and comes from the fact that agents apply only to more desirable districts.

The sorting of public servants in a single jurisdiction, where all residents are subject to the same taxation, raises two types of issues related to equity and efficiency. While issues related to inequities have been largely ignored in the literature, recent literature in the education market analyses ways to restore efficiency. First, one could change the **allocation mechanism**. For example, Combe et al. (2021) design matching mechanisms with the explicit objective of improving the balance of inexperienced teachers across schools. In this case, an improvement on the status quo is achieved thanks to choice restrictions. However, it is important to note that these restrictions may weaken the sorting patterns but not reverse them, as more desirable locations will remain oversubscribed.

As a consequence, in the rest of the analysis, we introduce transfers that modify preferences and, as such, introduce an **incentive to work** in disadvantaged areas. As transfers become a crucial component of the matching, our goal is to develop an empirical strategy to quantify the financial incentives required to achieve more desirable allocations. To that end, we develop an empirical model of the reallocation of officers to districts.

3.2 Preferences

In this section, we develop an empirical model to study the allocation of officers to police districts. Each period, risk-neutral officers choose districts to maximize their lifetime utilities. As the law of motion of our main state variable - seniority - does not vary across alternatives, we focus on the sequence of static decisions.[27] Our formulation of the problem also abstracts from any consideration of the first of district assignment on potential promotions as in reality, serving in a difficult district does not increase the likelihood of promotion.[28] Table 10 in the appendix shows that the location of the first assignment does not have any effect on the probability of promotion to sergeant and detective.

The preferences of police officers are specified using a random utility model. The (indirect) utility for assignment to a district d for officer i is given by v_{id}. Let $v_i = (v_{i1}, \ldots, v_{iD})$ be the random vector of indirect utilities for police officer i. The objective is to identify and estimate the the vector of random utilities v_i for all officers $i \in \mathcal{I}$.

The indirect utility an individual i derives from an assignment to district d depends on officer attributes $\boldsymbol{x}$, crime in the district $\boldsymbol{c}$, and other district attributes $\boldsymbol{z}$. Police officers are heterogeneous in observed attributes $\boldsymbol{x}$, including fixed variables (gender, ethnicity) and time-varying characteristics such as tenure in the police force, τ. Tenure affects preferences through wages, which are exogenously given by $w_d(\tau)$. In practice, base wages are set through bargaining between the city and the police union. However, other factors, such as overtime opportunities, vary across districts which allows us to use this component of wages as numeraire.

Districts are contiguous geographic units, which are heterogeneous in observed attributes $\boldsymbol{z}$ (e.g., racial/ethnic composition of the population and police force), and crime rates $\boldsymbol{c}$. The utility function is specified as:

$$\begin{aligned} v_{idt} &= v(\boldsymbol{x}_{it}, \boldsymbol{c}_{dt-1}, \boldsymbol{z}_{dt-1}, \delta_d, \epsilon_{idt}) + w_d(\tau_{it}), \\ v_{i0} &= 0 \,. \end{aligned} \tag{5}$$

where δ_d is the unobserved district characteristics, and ϵ captures idiosyncratic tastes for districts. The fundamental identifying assumption is that $\epsilon \perp\!\!\!\perp (w_{i1}, \ldots, w_{iD})$, which implies that any unobserved characteristics that affect the taste of police for districts are independent of wages. This scale normalization is embedded in the coefficient of wages. As a consequence, the parameters of the utility function measure the willingness to pay for district attributes.

[27] In characterizing the problem as a sequence of static decisions, we implicitly assume that there are no adjustment costs between districts. We abstract from moving costs because they would not have much impact on our economic analysis, while greatly increasing the computational complexity.

[28] The promotion process is relatively complex and it is unclear *a priori* whether serving in, for example, a more dangerous district makes an officer more likely to be promoted. In general, in order to be eligible for promotion to sergeant, officers must have "received 60 semester hours (90 quarter hours) of credit from an accredited college or university prior to the date the member is ordered to report for pre-service training". As such, education attainment acts as the first barrier to promotion. Then, police officers must follow a two-pronged examination system. Based on these results, a descending rank-order listing of candidates is compiled. Two thirds of positions are filled based on the performance on the test, while the remaining third is based, in part. on recommandations from previous supervisors. It is not clear that commanders from more dangerous districts are more likely to submit positive recommandations.

Each period of time, a district may have openings as police officers retire, die, resign from the force, or are fired. Information about vacancies is provided in "unit bulletin boards" and during roll calls. Upon learning about a vacancy, an interested police officer may submit a "bid". We assume that an officer i currently working in district d submits a bid for a vacancy in district ℓ if:[29]

$$v_{i\ell t} > v_{idt} \quad \forall \quad d \in \mathcal{D}. \tag{6}$$

The winning bid is that of the most senior officer among the qualified bids. In the case of a tie, the date of birth is used.

3.3 Neighborhood Crime Production Function

The economic content of officer preferences is limited without a causal statement on the effect of tenure on crime and police-civilian interactions. If, in the extreme, officer experience has no effect on the outcomes, the allocation of senior officers to safer neighborhoods is likely to result in limited efficiency losses. If, on the other hand, there are important returns to officer experience, the selection of senior officers into safer neighborhoods may result in substantial welfare losses due misallocation and there will be important equity considerations.

Formally, we are interested in the relationship between the composition of the police force and crime at the district level. We specify the production function as

$$c_{dt} = m(\tau_{dt}, z_{dt}, \psi_{dt}, \xi_{dt}). \tag{7}$$

where c_{dt} denotes the crime per capita at district d and time t. τ_{dt} are a set of statistics characterizing the experience of officers in district j at time t. The notation τ_{dt} is left unrestricted for now but should be general enough to account for nonlinearities in the effect of experience on crime. An assumption implicit in this specification of the crime production function is that the technology of experience accumulation τ_{dt} is similar no matter where an officer gains that experience. We explore this assumption empirically for the beat-level analysis in Appendix G. While the results are statistically insignificant, they suggest that, if anything, the returns to experience in deterring violent crime are smaller for officers who begin their careers in especially high-crime districts. More generally, there is not a clear reason to expect *ex ante* that being exposed to high levels of violent crime early in their career would improve an officer's ability to deter crime or to interact with civilians in a more productive or less aggressive manner.

There are two econometric unobservables, ψ and ξ. The terms ξ_{dt} are either measurement error or crime shocks that are not observable by officers before making their location decisions. In contrast, ψ_{dt} are district and time unobserved effects and potentially observed or predicted by officers. In practice, we specify the district effect as being additive and separable between district and time fixed effects $\psi_{dt} = \psi_d^{(0)} + \psi_t^{(1)}$.

The assignment mechanism implies non-random matching between officers and districts in a

[29] This assumption abstracts from a few technical rules governing the bidding process. In particular, each officer can bid for a single vacancy per period, and after submitting a successful bid, the officer cannot bid again for the next year. Given our estimation procedure, which is based on moment inequality conditions, we think abstracting from these technical rules has a negligible effect on our analysis.

way that may violate the traditional conditional independence assumption $\mathbb{E}(\xi_{dt}|\tau_{dt}, z_{dt}, \psi_{dt}) = 0$. Failure to account for this selection process will tend to provide upwardly biased estimates of the effect of tenure on crime. We discuss our identification strategy in the next section.

4 Estimation and Identification

Having specified a model of officer assignment and its impact on neighborhood crime, we now turn to a description of our empirical implementation. Estimation proceeds in three steps. We first focus on recovering the officer preferences underlying Chicago's current assignment mechanism and then turn to a discussion of identifying the causal impact of officer experience in the neighborhood crime production function. We conclude by describing our officer-level analysis, which uses detailed daily data on beat and shift assignments to study the effect of officer experience on arrests and use of force.

4.1 Officer Preferences

We use data on the identities of the officers that fill each vacancy to estimate the model of officer assignment and identify officer preferences over police districts. Identification follows from a standard application of revealed preferences.

Let θ be a set of parameters to be estimated with parameter space Θ, P is the true distribution of the data, and $\mathbf{P} = \{P_\theta : \theta \in \Theta\}$ denotes our model for the distribution of the observed data. Let $P_\theta^{\mathbf{m}}(y_{dl}|\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{c})$ describe mobility patterns such that

$$P_\theta^{\mathbf{m}}(y_{dl}|\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{c}) = \int P_\theta(\boldsymbol{v}_{il}(\theta) > \boldsymbol{v}_{id}(\theta)) \times P_\theta(\tau_i > \max(\tau_{-i}^\star)) \cdot \tag{8}$$

where $\boldsymbol{v}_\theta$ is the utility evaluated under parameter values θ, $\tau_{-i}^\star$ is the tenures of the set of individuals who apply to the vacancy in l, and y_{dl} indicating mobility from d to l. The integration is on the support of the unobserved determinants, which have been left out for notational convenience. Similarly, let $P_\theta^{\mathbf{c}}(\boldsymbol{c}|\boldsymbol{x}, \boldsymbol{z})$ denote the probability of a crime realization, and P_θ the joint realization of crime and mobility patterns. Assume the model is correctly specified in the sense that there exists $\theta \in \Theta$ such that $P_\theta = P$. Formally, the identification problem consists of determining under which conditions the solution to $P_\theta = P$ is unique.

Standard results in the discrete choice literature Matzkin (1992, 1993), based on revealed preferences, show that preference components are nonparametrically identified. Relative to a standard discrete choice model, the main difficulty in estimating preferences here is that mobility depends not only on preferences but also on matching constraints, namely the probability that the agent is the most senior bidder among interested officers. As such, likelihood-based methods may be impracticable, as they require to derive applications for each officer (which are not observed in the data), solve the allocation of officers given those applications, and finally simulate mobility patterns.

We use the *stability* property of the assignment mechanism to estimate the preferences of officers. Stability or *justified-envy-freeness* (Abdulkadiroglu and Sonmez, 2003) implies that each officer is matched to their favorite feasible district. We derive two main implications that apply when each

vacancy in a district d′ is filled and use these to create moment conditions:

1. **Officer who fills vacancy.** Any officer i who moves from district d to d′ prefers the new district. Thus, $v_{id't} > v_{idt}$.

2. **Officers who decline vacancy.** Any officer currently in district d who was senior enough to move to district d′ but chooses not to relocate prefers d to d′. Letting $\underline{\tau}_{dt}$ denote the minimum tenure required to move to district d′ at time t, this implies: $v_{idt} > v_{id't} \quad \text{if} \quad \tau_{it} > \underline{\tau}_{dt}$.

These moment conditions can be used to estimate preferences, similar to Pakes et al. (2015). An attractive feature of this set of conditions is that they capture all of the information provided by the data on filled vacancies. In total, there are 3,739,546 moment conditions, which are all used in the estimation. To facilitate the analysis, we make parametric assumptions. That is, the utility function is additive and separable:

$$v_{idt} = \alpha_c c_{dt-1} + \beta_c x_i c_{dt-1} + \delta_d + \epsilon_{idt} \,. \tag{9}$$

where α_k is a $||k||$ dimensional vector of parameters to be estimated. We further assume that:

$$\epsilon_{idt} \sim \mathcal{N}(0, \sigma_\epsilon^2) \,. \tag{10}$$

where the error term ϵ_{idt} is independent across officers, districts and time. Additionally, the unobserved district effects δ_d are assumed fixed.[30] In practice, under these sets of assumptions, the model can be estimated just as a binary discrete choice model, as each decision to move (or not) by an officer provides a binary outcome, and the preference parameters are point-identified.[31]

4.2 Neighborhood Crime Production Function

We turn next to the identification of the neighborhood crime production function. Formally, consider the identification problem of the effect of tenure on crime in a district:

$$c_{dt} = m(\tau_{dt}, z_{dt}, \psi_{dt}, \xi_{dt}) \,. \tag{11}$$

where, again, τ_{dt} is a set of statistics characterizing the experience of officers in the district. The main challenge in estimating equation 11 is that the assignment mechanism implies non-random matching between officers and districts in a way that is very likely to violate the traditional conditional independence assumption. If, for example, the systematic selection of more experienced officers into safer districts will result in a negative correlation between average officer tenure and ξ_{dt}. Failure to account for this selection process will tend to overstate the magnitude of the effect of officer experience on crime.

[30] We implemented a version of the model with random coefficients; however, preferences seem relatively uniform across officers such that the standard deviations of the random coefficients were close to 0.

[31] As the model is estimated using almost 4 millions moments, we could estimate the effect of any preference component. However, as we use administrative data, we have access to few officer characteristics. Consequently, we estimate the model separately by officer race/ethnicity, allowing preferences for crime rates, district characteristics, and district fixed effects to vary by officer race/ethnicity.

The inclusion of district fixed effects in equation 11 can help to mitigate much of this officer-driven selecion bias, but if officers respond to changes in crime rates over the study period, the potential for some selection bias remains. In order to correctly identify the effect of officer experience on neighborhood crime outcomes, therefore, we develop a simulated IV strategy motivated directly by the structure of the officer assignment problem. In particular, with estimates of the officer preferences in hand, we use a restricted version of the officer assignment problem to predict how each district's officer composition would have evolved if all district attributes (including crime rates) were held fixed at their initial levels and all vacancies were filled as predicted by the model. By construction, this simulated IV approach eliminates any change in district composition driven by the endogenous responses of officers to changing neighborhood crime patterns or any other time-varying neighborhood factors. The idea is inspired by Borusyak and Hull (2020), who argue for the importance of understanding whether there is non-random exposure to exogenous shocks in one's research design and suggest a solution based on simulating counterfactual shocks according to the valid data-generating process.

Formally, the identification requires $E(\tau^{\dagger}_{dt}\xi_{dt}) = 0$, where $\tau^{\dagger}_{dt}$ is the simulated tenure distribution. In practice, we consider two approaches to implementing our simulated IV strategy, noting that this distinction makes very little difference. In both cases, we predict officer responses to any vacancies based only on the district characteristics observed *in January of 2004*, which is three years before the first period of our study. Our first approach predicts how the vacancies observed in the data would be filled conditional on officers' current district assignments as observed in the data at the time of the vacancy. Our second approach tracks officer movement sequentially through the study period, predicting how officers respond to any vacancy given their current predicted location.[32] In our empirical application, we specify crime production function as a log-linear function:

$$\log \boldsymbol{c}_{dt} = \gamma_0 + \gamma_\tau \tau_{dt} + \gamma_z \boldsymbol{z}_{dt} + \psi^{(0)}_{d} + \psi^{(1)}_{t} + \xi_{dt} \cdot \tag{12}$$

We allow for the nonlinear effect of tenure by computing officers' share in tenure-bins in each district d during period t. The results are relative to officers with tenure of five years or less. Standard errors are obtained using 99 bootstraps.

It is well known that the curvature of the production function plays an important role in the aggregate impact of any reallocation. In particular, with an additive, linear production function, the reallocation of officers would simply shift crime from one district to another, without changing aggregate crime at all. The log-linear specification in equation 12 is attractive in that it implies that a social planner who aims to reduce crime should allocate the best officers to the locations with most crimes. It also allows the tenure composition of a district's officer to have a proportional effect on the number of crimes committed there. But imposing this log-linear specification *a priori* would raise the concern that the assumed functional form of the production function was driving the aggregate implications of our empirical analysis. For this reason, we provide a formal test of the log-linear specification by performing a Box-Cox transformation and estimating the following

[32] To make sure that the simulated number of officers in each district at each point in time matches the data, we simulate the creation of new vacancies in the district an officer leaves following either (i) predicted transfers between districts in the simulation or (ii) retirements (or transfers to special units) in the data that results in a replacement vacancy.

non-linear model via maximum likelihood:

$$c_{dt}(\lambda) = \gamma_0 + \gamma_\tau \tau_{dt} + \gamma_z z_{dt} + \psi_d^{(0)} + \psi_t^{(1)} + \xi_{dt}\,. \tag{13}$$

where

$$c_{dt}(\lambda) = \begin{cases} \dfrac{c_{dt}^{\lambda} - 1}{\lambda} & \text{if} \quad \lambda \neq 0 \\ \log(c_{dt}) & \text{if} \quad \lambda = 0 \end{cases} \,. \tag{14}$$

With this specification, the parameter λ governs the curvature of the production function. When $\lambda = 1$ the production function is perfectly linear. As λ approaches 0, the production function converges to a log-linear specification. We estimated this model as a extended version of the main specification of the production function reported in Table 4. The estimated value for λ equals to $0.061[-0.020, 0.104]$, implying that the log-linear specification fits the data very well, and much better than a linear specification. For simplicity, we use the log-linear assumption throughout the remainder of our paper.

5 Results

5.1 Preferences Estimates

Table 3 presents estimates for officers' preferences over district-level crime rates (α_c and β_c in equation 9). Estimates for Black officers are reported in column 1, for Hispanic officers in column 2, and for white officers in column 3. As the coefficients in the first two rows imply, all officers, regardless of race and ethnicity, have a distaste for districts with high rates of violent crime and a greater tolerance for those with more property crime. This is consistent with descriptive evidence documenting the movement of more senior officers towards low violent crime districts shown in Figure 2. The additonal interation terms shown in the final two rows, which add to those in the first two rows when the officer is female, indicate that the strength of these preferences is somewhat stronger for female officers.

Table 3: Officer's Preferences over Districts

	Main Specifications					
	Black		Hispanic		White	
	(1)		(2)		(3)	
Property Crimes	67.36***	(1.72)	64.84***	(2.1)	89.53***	(1.3)
Violent Crimes	-63.82***	(1.68)	-25.63***	(2.23)	-39.71***	(1.36)
Interactions with Officers Characteristics: Female						
Property Crimes	35.49***	(1.75)	60.99***	(2.21)	22.87***	(1.3)
Violent Crimes	-55.2***	(1.37)	-39.41***	(1.87)	-12.31***	(1.13)
Number of Inequalities	1121675		759836		1858035	

Notes: This table reports officer preferences over district-level criminality separately for Black officers (column 1), Hispanic officers (column 2), and white officers (column 3). Bootstrapped standard errors are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.

Appendix D reports additional preference parameter results. Figure D.1 confirms that officers gain greater utility from working with residents of a similar race and ethnicity. Black officers have the greatest preference for working in majority-black districts and the lowest preference for working in majority-white districts. White and Hispanic officers are similar in their preferences in that both dislike working in majority-black districts.

Figure D.2 presents a decomposition of average officer welfare over the course of a career, which isolates the importance of wages and preferrable district assignment. The results indicate that, in addition to higher wages, there is a sizeable non-pecuniary benefit that comes from the ability of officers to transfer to more preferable districts as they gain seniority.

5.2 Estimates of Officer Seniority on Crime

Table 4 presents estimates of the impact of officer tenure on district crime rates (γ_τ in equation 12).[33] As explained before, we use a log specification in this analysis, which implies that the mean dependent variable is negative. The first three columns report estimates for violent crimes and the last three shows estimates for property crimes. Columns (1) and (4) present basic OLS estimates including controls for officer characteristics (share of Black and Hispanic officers), the number of officers. Columns (2) and (5) include month-year by district (MD) fixed effects. Finally, columns (3) and (6) instrument the officer tenure distribution using the simulated IV. Section E in the appendix presents the fit of the simulated IV.

[33]District crime rate is calculated as the number of crimes in a month-year per 1,000 capita.

Table 4: Impact of Beat Officer Seniority on Crime - District Level

Tenure (years)	Violent Crimes			Property Crimes		
	(1)	(2)	(3)	(4)	(5)	(6)
Share Tenure = [5,10)	-0.499***	-0.034	-0.101**	0.606***	0.232***	0.08*
	(0.1)	(0.042)	(0.045)	(0.094)	(0.043)	(0.041)
Share Tenure = [10,15)	-2.756***	-0.467***	-0.191***	-0.616***	-0.278***	-0.071
	(0.111)	(0.056)	(0.05)	(0.122)	(0.06)	(0.044)
Share Tenure = [15,20)	-2.056***	-0.347***	-0.202***	-0.784***	0.159**	0.033
	(0.116)	(0.07)	(0.048)	(0.119)	(0.07)	(0.046)
Share Tenure = 20+	-1.843***	0.137	-0.183***	0.883***	0.323***	-0.026
	(0.153)	(0.093)	(0.047)	(0.193)	(0.093)	(0.046)
Mean DV	-5.809	-5.809	-5.809	-5.213	-5.213	-5.213
Number of Observations	2861	2861	2861	2861	2861	2861
Controls	X	X	X	X	X	X
Month-Year-District (MD)		X	X		X	X
Sim IV			X			X

Notes: This table reports elasticities of beat officer tenure on monthly crime rates. Controls include the share of Black and Hispanic officers, the total number of officers, and fixed effects for district, month, and year. Standard errors in parentheses are clustered at the district level. $^{***}p < 0.01$, $^{**}p < 0.05$,$^{*}p < 0.1$.

The simple OLS estimates presented in columns 1 and 4 suggest that more experienced officers have a very strong effect on both violent and property crime. As discussed above, however, we expect these estimates to severely overstate the causal impact of officer experience given the ability of senior officers to transfer into less violent districts. Indeed adding controls for district fixed effects significantly reduces the magnitude of these estimates for both violent and property crimes, as shown in columns 2 and 4.

Because neighborhood crime rates evolve over the study period, there is continued potential for OLS estimates to overstate the importance of experience even with the inclusion of district fixed effects. To deal with this continued endogeneity concern, columns 3 and 6 report the results of the simulated IV specification described in Section 4. These results indicate that a one percentage point increase in the share of officers with 5-10 years of experience (and reducing the share of officers with less than 5 years of experience by an equivalent amount) reduces violent crime rates by 0.10 percent. The returns to experience double to 0.20 percent for officers with 10-15 years of experience and remain roughly flat at the 0.20 level for officers with more than 15 years of experience. These results are a full order of magnitude smaller than those reported in column 1, implying substantial selection bias in simple OLS estimates. In contrast, there appear to be limited returns to officer experience in influencing property crime. The estimates for officers with more than 5 years of experience on property crime are mixed in sign, relatively small in magnitude (-0.07 to 0.08), and generally not statistically significant.

In summary, our results imply that increasing the share of more experienced officers in a district reduces violent crime, while having a negligible impact on property crime, in line with the results based on daily variation in officer assignment reported in Table 2 above.

6 Alternative Assignments - Efficiency and Equity

The results presented above show both significant returns to experience in policing and clear officer preferences for working in districts with lower violent crime rates. This combination raises important efficiency and equity concerns. Efficiency issues arise due to the potential misallocation of the most effective officers to neighborhoods where they have the least impact on crime. And the assignment of more experienced (and expensive) officers to higher-income, predominantly white neighborhoods raises obvious equity concerns given the effects of officer experience in reducing violent crime and their lower propensity to use of force and make discretionary non-index arrests. However, it is not clear ex-ante how police mobility, assignments, and crime would change under an alternative assignment system. This section considers the current assignment's shortcomings and outlines an alternative mechanism that may deliver welfare and equity gains.

6.1 Theory

Traditional design problems in economics often consist of finding allocation mechanisms that restore efficiency. These reforms are motivated by the observation that specific mechanisms lack desirable properties, such as stability (Roth and Peranson, 1999) or strategy-proofness (Abdulkadiroglu et al., 2011). In our setting, efficiency and equity concerns originate not from properties of the assignment mechanism but from the priority structure, which steers experienced officers away from neighborhoods where they would have had the greatest impact. One may be tempted to introduce some randomness in the assignment system, such as a lottery system. However, a lottery would not solve the root problem unless officer mobility was severely restricted.

Building on the observation that the incentives to work in higher crime districts are weak (or non-existent), we design an alternative mechanism that introduces an incentive to work in the higher crime districts by offering monetary subsidies. Similar structures exist in various countries for medical doctors and teachers. Specifically, we maintain the bidding process with seniority preference precisely as it works under the current mechanism but introduce a set of district-experience-specific transfers. We implement this policy in a revenue-neutral way and keeps the number of positions in each district at the level observed in the data.

To provide a clear sense of the equity and efficiency properties of the current allocation mechanism, we calculate the set of net subsidies that would achieve an equitable allocation of officers by experience across districts. We do so in a manner that preserves the current average dynamic indirect utility profile to minimize any dynamic selection effects — i.e., changes in the incentive to enter the police force initially or to exit at any point in the career. In practice, we implement a head tax to collect the revenue needed for the subsidies and calculate district-specific subsidies needed at each experience level to induce enough officers to willingly self-select into each district until an equitable distribution is achieved.

Formally, let $\mathcal{T} = \{\tau^{(1)}, \ldots, \tau^{(m)}\}$ denote the vector of officer shares for different tenure level. An equitable allocation $\mu^{\ddagger}$ is such that

$$\mu^{\ddagger} = \arg\min || \sum_{j} \mathcal{T}(\mu_j^{\ddagger}) - \mathcal{T} || \cdot \tag{15}$$

Under the equitable assignment, crime outcomes are not directly targeted but rather the tenure profile of officers in each district. Any crime reductions, therefore, are attributed to the allocation component of officers. We find the set of district-experience specific wage contracts that provide sufficient incentives to reach an equitable allocation of officers across districts. Formally, let $\mathcal{W} : \{\mathcal{W}_j(\tau)\}_{j\in\mathcal{D}}^{\tau\in}$ denote a set of wage-tenure district contracts and μ denote a desirable allocation, which depends on the preferences of officers and wages across districts denoted by $\mu(\Theta, \mathcal{W})$. The wage-tenure-district contract $\mathcal{W}^\star$ is given by:

$$\mathcal{W}^\star = \arg\min_{\mathcal{W}^\star} ||\mu(\Theta, \mathcal{W}^\star) - \mu^\ddagger|| \text{ . } \tag{16}$$

As stated, equation 16 defines a mapping between wages and a spatial allocation of officers. Brouwer's fixed-point theorem guarantees that a solution exists. Further, for a given allocation, equation 16 defines a system of $\mathcal{D} \times \mathcal{T}$ equations with $\mathcal{D} \times \mathcal{T}$ unknowns (wages), which guarantees a unique solution. We recover the wages following the intuition for the fixed-point iteration: increasing the wage subsidy until it reaches the target allocation.

6.2 Results

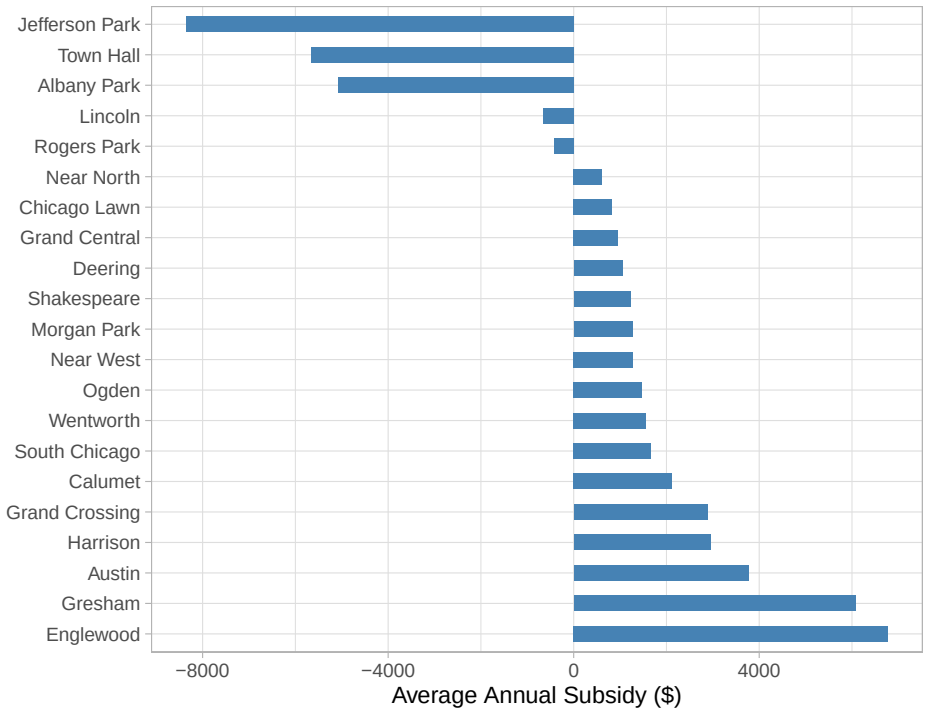
6.2.1 Net Subsidies and Officer Welfare

Figure 6 presents the net subsidies for each district required to generate an equitable allocation of officers by experience across districts. The numbers reported are the average of the subsidies across all years of officer experience. Not surprisingly, a substantial positive subsidy is necessary to incentivize officers to transfer to districts with greater violent crime. For example, an annual subsidy of approximately $6,200 is required to induce enough officers to choose the most violent neighborhood, Englewood, while officers who choose one of the safest and most desirable neighborhoods, Jefferson Park, must forgo about $8,050 in annual pay relative to the current equilibrium.

As mentioned above, we implement these net subsidies in a manner that preserves the average dynamic indirect utility profile, which is shown in the left panel of Figure 7. Under the current mechanism, the indirect utility of officers increases as they gain experience through two mechanisms: (i) higher wages and (ii) more preferable district assignments. Under equitable assignment, the latter mechanism is shut down, and so a steeper wage gradient is required to preserve the overall indirect utility profile. The right panel of Figure 7 shows the wage profile under the current equilibrium and in our equitable counterfactual. In the counterfactual, officers start their careers at a lower wage on average (they gain indirect utility from more favorable initial district assignments in the counterfactual). At the same time, more seniors are compensated for the loss of favorable district assignments with significantly higher wages.

The small positive level shift in the indirect utility profile shown in the left panel of Figure 7 indicates that officers on the whole gain welfare under the alternative assignment mechanism. The welfare increase is small — only about 2 percent. That an equitable allocation of officers by tenure across districts leads to only a small change in average officer welfare follows directly from two key features of the alternative assignment mechanism. First, because we have implemented equitable assignment in a manner that is revenue neutral and keeps the number of positions in each district the

Figure 6: Average Subsidy by District



Notes: This figure depicts the average annual subsidy required to incentivize officers to transfer to that district. Districts are listed in increasing order of the subsidy amount.

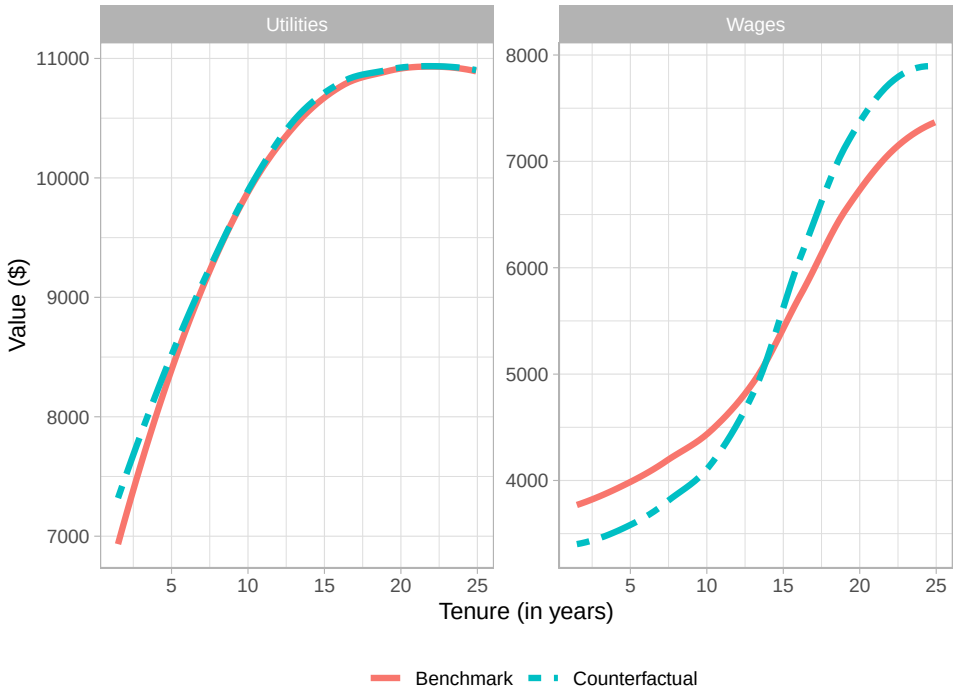
same as in the data, the alternative assignment is simply a transfer of wages and district assignments between officers. This eliminates any first-order effects on officer welfare that would occur under an alternative that, for example, used additional resources to finance a subsidy program. Second, the alternative mechanism continues to allow officers to self-select into districts, ensuring that, at each experience level, officers with especially strong preferences for a given location are able to satisfy those preferences.

While it might be surprising at first glance, the fact that the alternative mechanism generates a small overall *gain* in officer welfare relative to the current equilibrium is related to a well known limitation of the deferred acceptance allocation mechanism: that it does not respond to the intensity of preferences.[34] Under the alternative mechanism, young officers have a greater opportunity to act upon intense preferences for desirable districts, rather than being "outbid" by more senior officers

[34]To see this, consider two officers $\{1\}, \{2\}$ and two districts $\{a\}, \{b\}$, with the preferences described by the next table. Under the current allocation, officer $\{1\}$ gets assigned to $\{a\}$, and officer $\{2\}$ is assigned $\{b\}$ and total welfare is equal to 11. Now consider our alternative mechanism, where we implement a revenue neutral transfer, $\{1\}$ gets assigned to $\{b\}$, and officer $\{2\}$ is assigned $\{a\}$, total welfare is equal to 17.

Officers	Benchmark		Counterfactuals	
Utilities	Districts		Districts	
	a	b	a	b
$\{1\}$	10	8	6	12
$\{2\}$	9	1	5	5

Figure 7: Utility and Wage Profiles by Officer Seniority



Notes: This figure depicts the average indirect utility of officers by tenure on the left and average wage-career profile on the right. The red line displays the benchmark profiles under the current system, while the blue dashed line displays the utility and wage profiles under our proposed mechanism.

with less intense preferences. Consider, for example, an officer with especially strong idiosyncratic preferences to work in a district with a low violent crime rate—e.g., Jefferson Park—perhaps because it is close to home. Under the current mechanism, this officer would typically need to wait many years to gain the seniority required to move to the district. Under the alternative mechanism, however, officers can choose to work in any district at any experience level, provided they are willing to forgo the subsidies designed to induce officers to choose higher crime districts. In this way, the alternative mechanism allows some young officers to satisfy the intensity of their preferences, and thus it yields a more efficient overall allocation.

Importantly, the fraction of Black officers working in predominantly Black neighborhoods also increases in the counterfactual equilibrium. This result is driven naturally by the fact that Black officers have *relatively* stronger preferences to work in these districts and, as a result, are more likely to respond to any subsidies on the margin. In this way, inexperienced white and Hispanic officers currently working in these districts are replaced by more senior Black officers in the counterfactual equilibrium.[35]

Finally, equalizing tenure has a heterogeneous impact on officers. In particular, because districts with higher violent crime rates are subsidized in the counterfactual, officers who are more willing to work in these districts benefit under the alternative design. As Figure C.1 shows, Black officers are more likely to work in these districts in the current equilibrium. Thus, not surprisingly, on average Black officers gain welfare (about $3,000 per year), and white officers lose welfare (about $2,000 per year) under the alternative assignment mechanism. While not enormous, these welfare gains (losses) may induce more (less) Black (white) officers to select into the CPD. This aligns with a long expressed policy goal of the CPD, which has failed to increase Black recruitment despite departmental efforts to increase diversity among recruits.[36]

6.2.2 Effects on Aggregate and Neighborhood Crime Rates

Table 5 shows the aggregate city-wide effects of the equity-based matching allocation on violent and property crime. As a benchmark, we report in the first column the monthly number of crimes per 1,000 residents in Chicago, averaged over the full period (2007-2017). The second column reports the predicted crime rates in the counterfactual assignment mechanism, which equalized officer tenure profiles across districts. The third column presents the percentage change relative to the benchmark.

We present the effect of equalizing tenure on violent crimes, property crimes and use of force. The two panels of Table 5 present results based on production function estimates derived from the two broad sources of variation used in our analysis described above: (i) the simulated IV results using district-month variation and (ii) the MDD and MDSB analyses, which exploit daily vairation in officer assignment derived from the CPD's rotating schedule. There is no reason to expect these different sources of variation to lead to identical outcomes given the different sources of variation used in the analyses.

[35] While not explicitly incorporated in our analysis here, recent research suggests that a better match between officer and civilians on the basis of race and ethnicity leads to better police-civilian interactions along a number of dimensions (see Ba et al. (2021)).

[36] See https://www.chicagotribune.com/news/breaking/ct-met-chicago-police-hiring-20180503-story.html.

Table 5: Aggregate Effects on Neighborhood Crime

	Monthly district variation: Sim IV			Daily district variation		
	Benchmark	Counterfactual	Change (%)	Benchmark	Counterfactual	Change (%)
Panel A: Violent Crimes						
Average	4.819	4.596	-4.617	4.721	4.5227	-4.2
Max-min ratio	10.465	7.117		10.120	7.319	
Panel B: Property Crimes						
Average	7.277	7.281	0.05	7.416	7.421	0.06
Max-min ratio	6.204	6.846		7.269	7.079	
Panel C: Use of force						
Average				1.72	1.55	-10.201
Sd				0.768	0.642	

Notes: This table reports the aggregated effects of the equity-based matching allocation separately for violent crimes (Panel A) and property crimes (Panel B) and use of force (Panel C). We report estimates using monthly variation at the district level and daily variation at the beat level. These estimates comes from two separate methods - simulated IV and poisson regressions with day of the week, year, month and district fixed effects. Benchmark (monthly) numbers report the average monthly number of crimes and use of force per 1,000 residents in Chicago averaged over 2007 and 2017. Max-min ratio is the ratio of the largest rate and the smallest rate. Counterfactual numbers report the crime rates in the counterfactual assignment mechanism. As there are many 0s in the use of force data, we report the sd instead of the max-min ratio.

Overall, equalizing tenure across districts would have little effect on property crime while leading to a sizable decline in the aggregate violent crime rate of -4.6% relative to the benchmark. This is a substantial effect on violent crime relative to the existing literature that studies the impact of various aspects of policing on crime.[37] Interesting, counterfactuals based on crime production function estimates that exploit daily variation in assignment due to the rotational calendar structure lead to almost identical results. In this case, the estimates imply that equalizing tenure across districts leads to a -4.2% reduction relative to the benchmark.

In order to put our results into a larger context, let's recall that Mello (2019), for example, estimates the elasticity of violent crime to the number of officers employed by a department to be about 1.3. Thus, achieving a 4.5% decline in violent crime in Chicago would require a 3.5% increase in department size, roughly equivalent to hiring 300 new officers.[38] Our alternative assignment mechanism delivers this aggregate violent crime reduction not only at no additional cost to the city but also with a predicted reduction in discretionary arrests and use of force in Chicago's poorest and most segregated Black neighborhoods. More specifically, we find that equalizing tenure would lead to a 10% reduction in use of force.

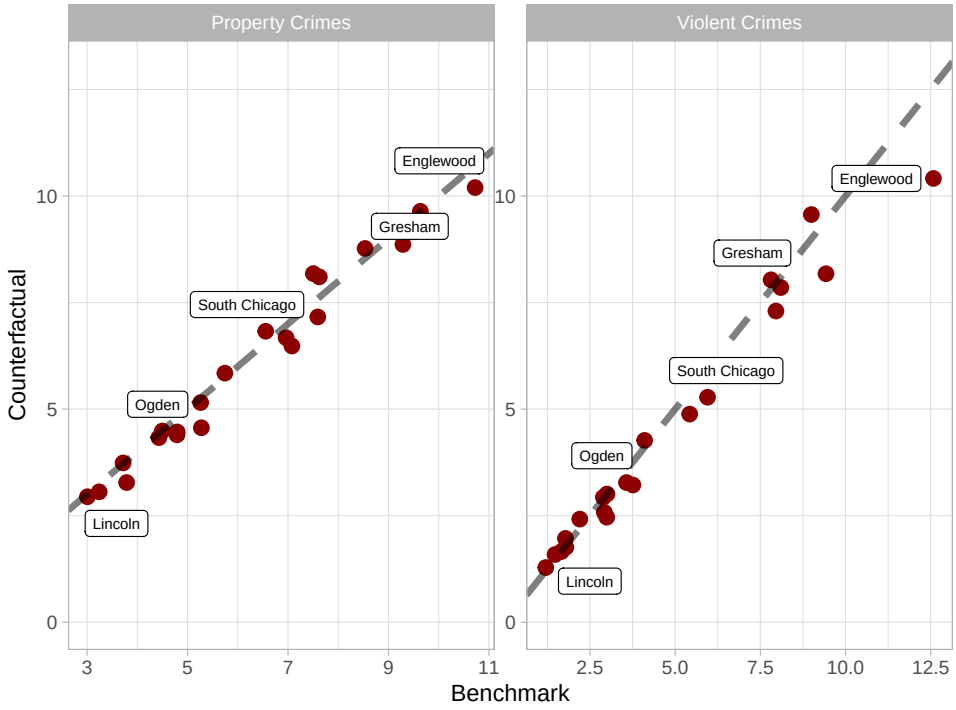
The aggregate reduction in Chicago's violent crime rate under the counterfactual comes about because, relative to the current equilibrium, more experienced officers are assigned to the districts with the highest violent crime rates. Thus, not surprisingly, the alternative assignment mechanism

[37] The finding that tenure has little effect on property crime is generally consistent with the literature on police employment and arrest rates on property crime, which generally find either economically or statistically non-significant elasticities with respect to property crime.

[38] Mello (2019) focuses on index crimes.

also induces a significant decline in the inequality of exposure to violent crime across districts. Figure 8 plots the counterfactual property and violent crime rates for each district relative to their observed levels for October 2007. The gray dashed line is a 45-degree line. Districts (circles) above this line experience additional crime in the counterfactual state relative to the benchmark. Districts (circles) below the line indicate those that experience less crime.

Figure 8: Distributional Changes in Crime across Districts



Notes: This figure depicts each district's counterfactual property and violent crime rates (on the y-axis) relative to their observed October 2007 levels (on the x-axis) for all CPD districts excluding downtown. The gray dashed line is a 45-degree line.

There is a substantial reduction of violent crime in the highest crime districts. Violent crime declines by 16.8% in Engelwood, for example, under the alternative assignment mechanism. Overall, the ratio of the violent crime rate in the district with the highest versus lowest rate declines from 10.5 to 6.1 in the counterfactual, highlighting the equity benefits of a policy that allocates experienced officers more equally across the city. Finally, given the estimated effects of officer experience on discretionary arrests and use of force shown, we would also expect an equitable assignment of experienced officers to lead to a substantial reduction in these outcomes in the neighborhoods of Chicago with the highest violent crime rates as documented by the reduction in the variance of use of force in the panel C of table 5.

7 Conclusion

This paper studies the impact of the seniority-based mechanism through which police officers are assigned to neighborhood districts in Chicago. Officers of all races and ethnicities exhibit a strong

preference to work in safer districts, leading to a substantial over-representation of the least experienced officers in the highest crime districts in Chicago. We find that experienced officers deter violent crime, while making fewer discretionary (non-index crime) arrests and using less force against civilians.

To assess the welfare consequences of Chicago's pure seniority-based assignment mechanism, we simulate an alternative allocation that incentivizes senior officers to choose less desirable districts. The results imply that equalizing officer tenure across districts would result in clear gains in efficiency and equity. In the counterfactual, violent crime declines sharply in the highest crime neighborhoods and by 4.6 percent in the city as a whole. There is a substantial reduction in discretionary arrests and use of force in neighborhoods with the largest fraction of Black residents. More subtly, average officer welfare improves by a small amount, as the alternative mechanism allows officers to better satisfy intense locational preferences over their full careers.

In summary, our analysis implies that there are significant costs (crime and police-civilian interactions) to employing a pure seniority-based assignment mechanism. Our results suggest that significant gains in average civilian and officer welfare, lower crime rates, reduced use of force, and a more equitable allocation of police resources across neighborhoods are all possible under a modified seniority-based mechanism.

This intervention reduces violent crime, especially in the poorest neighborhoods, without increasing arrests, use of force, or the police operating budget. Additionally, there may be welfare gains that go beyond our analysis. Deterring violent crime through the more efficient deployment of experienced, senior officers would potentially improve police-civilian interactions without deteriorating public safety (Lum and Nagin, 2017; Rivera and Ba, 2019), lower the criminal justice cost associated with punishing minor offenses (Agan et al., 2021), reduce the cost of subjecting innocent persons to enforcement (Donohue and Levitt, 2001; Durlauf, 2006; Manski and Nagin, 2017; Rivera, 2022), and reduce negative spillovers of the use of force (Ang, 2021).

Finally, it is worth stressing that many interventions designed to lower violent crime are unlikely to achieve that goal without substantial increases to the budget (via new programs or adding new officers) or increasing police-civilian interactions. The alternative assignment mechanism proposed here decreases violent crime without sacrificing the budget or public safety. Moreover, the more equitable assignment of experienced officers to the highest crime neighborhoods also brings the potential for improving the lives of residents by helping to reduce both violence and negative interactions with the police.

References

Abdulkadiroglu, A., Y.-K. Che, and Y. Yasuda (2011, February). Resolving Conflicting Preferences in School Choice: The Boston Mechanism Reconsidered. *American Economic Review 101*(1), 399–410.

Abdulkadiroglu, A. and T. Sonmez (2003, June). School Choice: A Mechanism Design Approach. *American Economic Review 93*(3), 729–747.

Adda, J., B. McConnell, and I. Rasul (2014). Crime and the depenalization of cannabis possession: Evidence from a policing experiment. *Journal of Political Economy 122*(5), 1130–1202.

Agan, A. Y., J. L. Doleac, and A. Harvey (2021, March). Misdemeanor Prosecution. Technical Report w28600, National Bureau of Economic Research.

Agarwal, N. and P. Somaini (2018). Demand analysis using strategic reports: An application to a school choice mechanism. *Econometrica 86*(2), 391–444.

Ang, D. (2021, February 2021). The effects of police violence on inner-city students. *Quarterly Journal of Economics 136*(1), 115–168.

Ba, B. A. (2018). Going the extra mile: the cost of complaint filing, accountability, and law enforcement outcomes in chicago. *Working paper*.

Ba, B. A., D. Knox, J. Mummolo, and R. Rivera (2021). The role of officer race and gender in police-civilian interactions in chicago. *Science 371*(6530), 696–702.

Blanes i Vidal, J. and T. Kirchmaier (2017, 09). The Effect of Police Response Time on Crime Clearance Rates. *The Review of Economic Studies 85*(2), 855–891.

Borusyak, K. and P. Hull (2020, September). Non-random exposure to exogenous shocks: Theory and applications. Working Paper 27845, National Bureau of Economic Research.

Boyd, D., H. Lankford, S. Loeb, and J. Wyckoff (2005, May). Explaining the short careers of high-achieving teachers in schools with low-performing students. *American Economic Review 95*(2), 166–171.

Chalfin, A. and J. McCrary (2017, March). Criminal deterrence: A review of the literature. *Journal of Economic Literature 55*(1), 5–48.

Clotfelter, C. T., E. J. Glennie, H. F. Ladd, and J. L. Vigdor (2008). Teacher bonuses and teacher retention in low-performing schools: Evidence from the north carolina $1,800 teacher bonus program. *Public Finance Review 36*(1), 63–87.

Clotfelter, C. T., H. F. Ladd, and J. L. Vigdor (2006). Teacher-student matching and the assessment of teacher effectiveness. *The Journal of Human Resources 41*(4), 778–820.

Combe, J., U. Dur, O. Tercieux, C. Terrier, and U. Unver (2021). A market design solution to the unequal distribution of teachers in schools.

Combe, J., O. Tercieux, and C. Terrier (2018). The design of teacher assignment: Theory and evidence.

Di Tella, R. and E. Schargrodsky (2004, March). Do police reduce crime? estimates using the allocation of police forces after a terrorist attack. *American Economic Review 94*(1), 115–133.

Donohue, J. J. and S. D. Levitt (2001). The impact of race on policing and arrests. *The Journal of Law & Economics 44*(2), 367–394.

Draca, M., S. Machin, and R. Witt (2011, August). Panic on the streets of london: Police, crime, and the july 2005 terror attacks. *American Economic Review 101*(5), 2157–81.

Durlauf, S. N. (2006). Assessing racial profiling. *The Economic Journal 116*(515), F402–F426.

Eeckhout, J., N. Persico, and P. E. Todd (2010, June). A theory of optimal random crackdowns. *American Economic Review 100*(3), 1104–35.

Evans, W. N. and E. G. Owens (2007, February). COPS and crime. *Journal of Public Economics 91*(1-2), 181–201.

Fack, G., J. Grenet, and Y. He (2019, April). Beyond truth-telling: Preference estimation with centralized school choice and college admissions. *American Economic Review 109*(4), 1486–1529.

Fu, C. and K. I. Wolpin (2017, 11). Structural Estimation of a Becker-Ehrlich Equilibrium Model of Crime: Allocating Police Across Cities to Reduce Crime. *The Review of Economic Studies 85*(4), 2097–2138.

Hanushek, E. A., J. F. Kain, and S. G. Rivkin (2004). Why public schools lose teachers. *The Journal of Human Resources 39*(2), 326–354.

Jackson, C. (2009). Student demographics, teacher sorting, and teacher quality: Evidence from the end of school desegregation. *Journal of Labor Economics 27*(2), 213–256.

Kelling, G. L. and J. Q. Wilson (1982). Broken windows: The police and neighborhood safety. *Atlantic Monthly 249*, 29–38.

Levitt, S. D. (1997, June). Using Electoral Cycles in Police Hiring to Estimate the Effect of Police on Crime. *American Economic Review 87*(3), 270–290.

Lum, C. and D. S. Nagin (2017). Reinventing american policing. *Crime and Justice 46*, 339–393.

Manski, C. F. and D. S. Nagin (2017). Assessing benefits, costs, and disparate racial impacts of confrontational proactive policing. *Proceedings of the National Academy of Sciences 114*(35), 9308–9313.

Mas, A. (2006). Pay, reference points, and police performance. *The Quarterly Journal of Economics 121*(3), 783–821.

Mastrobuoni, G. (2020, 03). Crime is Terribly Revealing: Information Technology and Police Productivity. *The Review of Economic Studies 87*(6), 2727–2753.

Matzkin, R. L. (1992, March). Nonparametric and Distribution-Free Estimation of the Binary Threshold Crossing and the Binary Choice Models. *Econometrica 60*(2), 239–70.

Matzkin, R. L. (1993, July). Nonparametric identification and estimation of polychotomous choice models. *Journal of Econometrics 58*(1-2), 137–168.

McCrary, J. (2002). Using electoral cycles in police hiring to estimate the effect of police on crime: Comment. *American Economic Review 92*(4), 1236–1243.

McCrary, J. (2007, March). The effect of court-ordered hiring quotas on the composition and quality of police. *American Economic Review 97*(1), 318–353.

Mello, S. (2019). More cops, less crime. *Journal of Public Economics 172*, 174 – 200.

Miller, A. R. and C. Segal (2018, 09). Do Female Officers Improve Law Enforcement Quality? Effects on Crime Reporting and Domestic Violence. *The Review of Economic Studies 86*(5), 2220–2247.

Pakes, A., J. Porter, K. Ho, and J. Ishii (2015). Moment inequalities and their application. *Econometrica 83*(1), 315–334.

Pathak, P. A. (2011). The mechanism design approach to student assignment. *Annual Review of Economics 3*(1), 513–536.

Prendergast, C. (2021, February). Drive and wave: The response to lapd police reforms after rampart. Working paper.

Rivera, R. (2022). The effect of minority peers on future arrest quantity and quality. Working Paper.

Rivera, R. and B. A. Ba (2019). The Effect of Police Oversight on Crime and Allegations of Misconduct: Evidence from Chicago. *SSRN Electronic Journal*.

Roth, A. E. and E. Peranson (1999, September). The redesign of the matching market for american physicians: Some engineering aspects of economic design. *American Economic Review 89*(4), 748–780.

Weisburd, S. (2019, 12). Police Presence, Rapid Response Rates, and Crime Prevention. *The Review of Economics and Statistics*, 1–45.

A Data

The data for this paper were obtained via Freedom of Information Act (FOIA) requests from the Chicago Police Department, Department of Human Resources, Department of Finance. Additional data were collected from the City of Chicago's open data portal, the decennial US Census 2014, and the American Community Survey.

A.1 Source Data

We obtained administrative records and information on sworn officers using Freedom of Information Act (FOIA) requests to the Chicago Police Department (CPD) and the city's Human Resources Department. CPD provided rosters of all available officers during our sample period (2007-2017), demographic information (race, gender, and birth year), appointment date, unit assignment history, daily shift and beat assignment histories, arrests, and use of force incidents. The Chicago Department of Human Resources provided data on officers' salary, rank, and pay grade from the collective bargaining agreement (CBA). The information about police officers is supplemented with data on reported crime incidents in the city from 2001 to 2020. The dataset contains the type of crime, the date, and the location of each incident.

A.2 Officer Level Data

For individual officer analyses, we employ arrest, use of force, and daily assignment data. Arrest data contain arresting officers, arrestees characteristics, arrest date and time, and alleged crime type for all arrests of adults between 2010 and 2019. The use of force data from 2010 to 2018 contains all reported uses of force based on tactical response report (TRR) filings by CPD officers for incidents involving adults, including date and time, subject characteristics, and officers. Daily assignment data includes information on each officer's watch and shift, start and end times, present for duty status, absence information, and assigned beat for all officers working in the geographic units between 2010 and 2017. Essentially this data allow us to observe, for patrol officers in the largest units, precisely when and where (either location or function) they worked each day, as well as their observable actions while they worked.

A.3 Sample Construction

Our primary sample consists of 16,859 distinct police officers from 2007 to 2017, resulting in a total of 1,550,177 officer-month observations. We restrict our analysis to non-probationary police officers with pay grade D1 (i.e., a regular patrol or beat officer). According to the CBA and the rosters we have received via FOIA, these officers constitute the vast majority of officers. We further exclude officers who are not assigned to a geographical district, as our analysis focuses on the impact of neighborhood assignment on crime and police-civilian interactions. These sets of restrictions allow us to track patrol officers performing similar tasks and compensation based on the same pay schedule. We limit our analysis to Black, Hispanic, and white officers representing about 97% of the force. Our final sample consists of 1,060,662 monthly officers' assignments. In the initial period,

our panel includes 8,313 patrol officers. During the study period, 4,531 officers retired, while CPD recruited 3,743 new officers.[39]

A.4 Crime

Data from 2001 to the present are publicly available on the City of Chicago's open data portal and were downloaded on August 20th, 2020. This data contains all reported crimes in Chicago, including the date and time, case number, type and description, whether or not it was cleared by arrest, and the coordinates of the crime. This data is aggregated by district, month, and crime type. Crime types are aggregated crime types, including violent (murder, criminal sexual assault, aggrevated assault and battery, robbery, manslaughter,and and simple battery and assault), property (burglary, theft, arson, motor vehicle theft, fraud, stolen property, embezzelment, forgery, vandalism), drug (non-index drug-related crimes), and other (warrant arrests, traffic crimes, municipal code violations, . . .). Effectively, the violent and property crime categories includes all index crimes with the addition of non-index crimes that are relevant, and non-index refers to all other crimes.

Districts and Populations Before 2012, there were 25 geographic districts, and three of the smaller districts were absorbed by other districts during 2012, resulting in 22 districts at the beginning of 2013. The 'current' district map was obtained from the open data portal, and the pre-2012 district map was constructed using the Chicago Police Department's 2008 report.

The populations and income of these districts are based on the US 2010 Census populations and 2014 ACS, respectively. First, the pre-2012 map of districts divided into beats was used to aggregate over census tracts, which supplies the populations for pre-2012. A crosswalk was built based on overlapping areas to determine the precise frontier of units in 2012.

Demographics Demographic data, such as race, birth year, appointed date, and gender, are contained in multiple files. Individual data sets are merged iteratively to create a reference data set containing the maximal amount of information on individual officers across files. Officers' final demographics, which may be conflicting between files (though this is very rare), are determined by the most common non-missing value across files.

Salary Data on officer salary, rank, pay grade, and promotion date were obtained via FOIA request to the Department of Human Resources in 2017. They contain sworn and probationary officer information between 2002 and 2017.

Earnings Data on officers' annual earnings (all forms of compensation, including salary and overtime) were obtained via FOIA request to the Department of Finance in 2019.

Unit History Data on the history of units in which an officer worked was obtained via FOIA request from the Chicago Police Department in 2020. This data contains the assignment of each officer as well as the start and end date of the assignment.

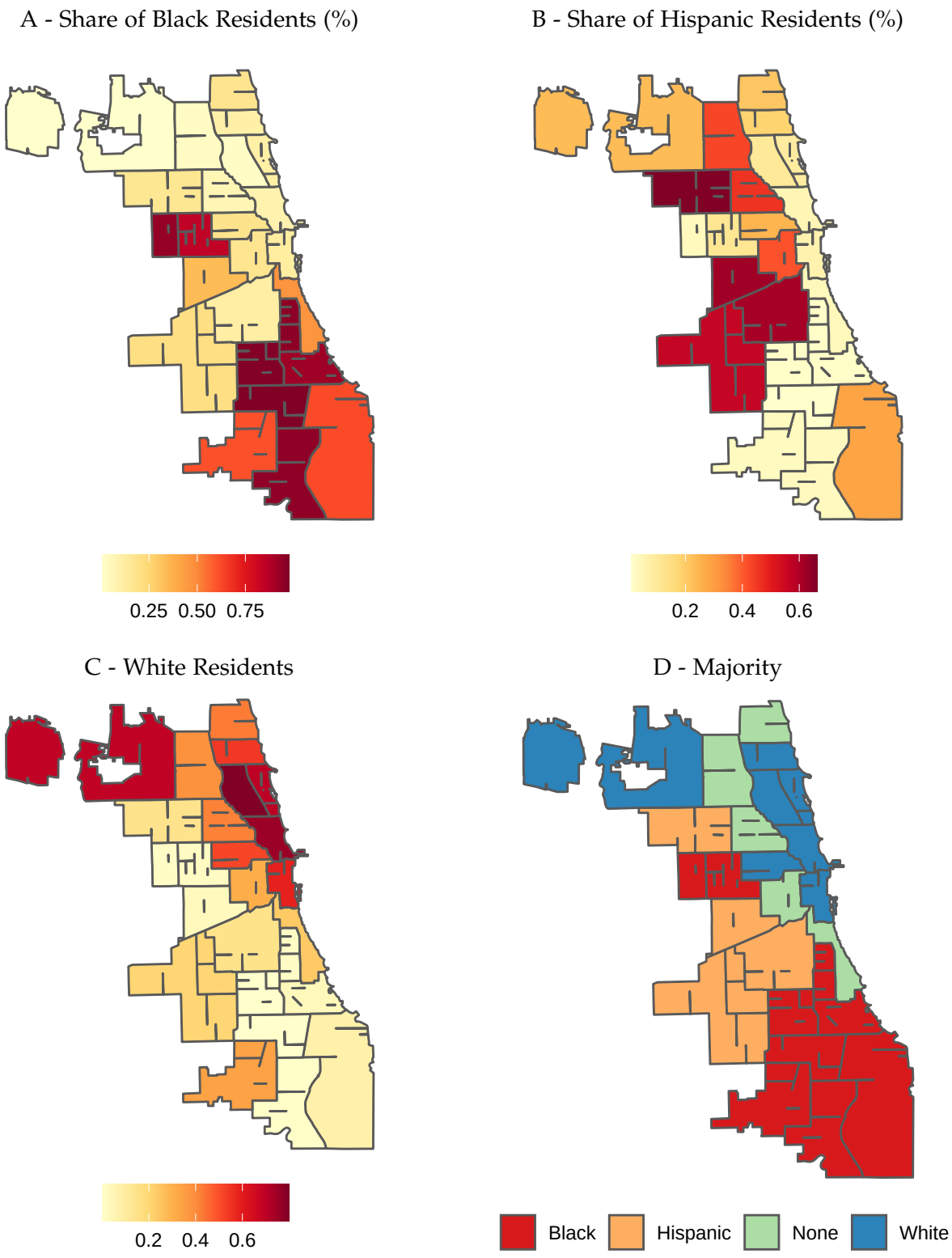
[39]The Chicago Police Department merged a few smaller districts in 2012, reducing the number of districts from 25 to 22. For our analysis, we use the current geographic boundaries to define districts throughout the study period consistently.

Arrests Data on all arrests made by Chicago police officers of adults between 2010 and 2019 were obtained via FOIA request to the Chicago Police Department in 2020. This data contains the primary arresting officers, central booking number, arrest date and time, crime type, and arrestee demographics.

Use of Force Data on all force use incidents against adults (with known ages) reported by Chicago police officers between 2004 and 2018 were obtained via FOIA request to the Chicago Police Department in 2018. Reports are called Tactical Response Reports (TRR) and contain information on each officer using force, subject race, incident date and time, level of force used, and subject and officer status.

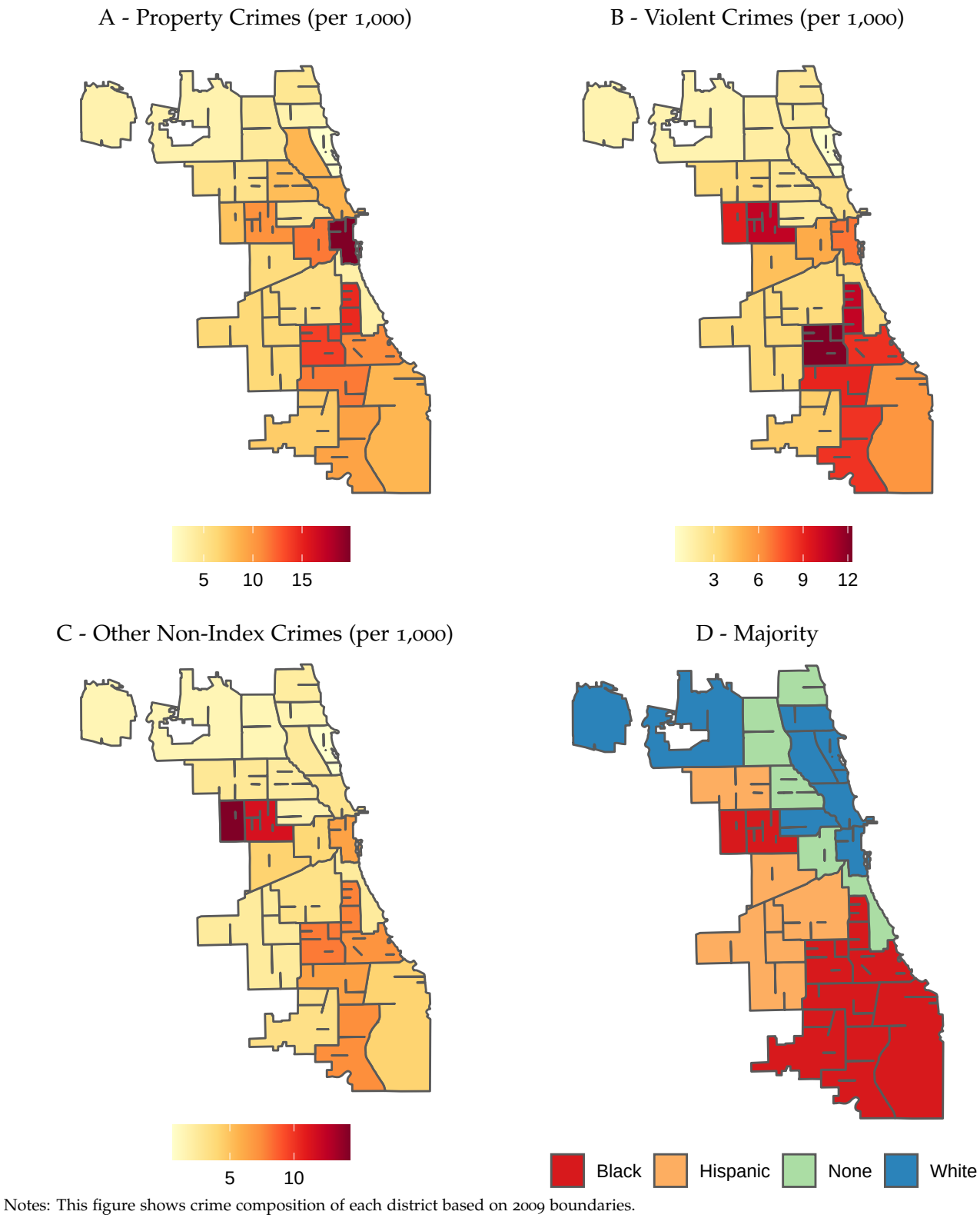
B Police, Crime and Segregation in Chicago

Figure B.1: Residential Segregation



Notes: This figure shows racial composition of each district based on 2009 boundaries.

Figure B.2: Crime Segregation



Notes: This figure shows crime composition of each district based on 2009 boundaries.

C Description of the CPD

C.1 Police Force

Table 6 displays the changing composition of the CPD from 2007 to 2017, and can be summarized in three main facts. First, the number of officers in the sample fluctuates from year to year depending on hiring and retirements; however, the force's size declines over the sample period. This decline is due to both increasing retirements and generally lower hiring by the department. As a result, while the share of female officers has remained relatively stable, there has been a decline in Black share and an almost equivalent increase in Hispanic share over the period. Lastly, the mobility rate (likelihood of an officer switching units) fluctuates from 3% to 8%, which is in line with other public servants.[40]

Table 6: Officers' characteristics

Year	Number of Police Officers	Retirements	New Police Officers	Mobility Rate	Share of Police Officers		
					Black	Hisp.	Female
2007	8310				0.30	0.18	0.26
2008	8582	346	616	0.05	0.29	0.19	0.26
2009	8727	182	521	0.06	0.29	0.20	0.26
2010	8816	312	281	0.06	0.29	0.20	0.26
2011	8627	271	112	0.06	0.28	0.21	0.26
2012	8482	446	127	0.08	0.28	0.21	0.26
2013	8135	292	104	0.03	0.28	0.21	0.25
2014	7909	467	76	0.03	0.28	0.21	0.25
2015	8096	463	661	0.08	0.26	0.23	0.24
2016	7954	612	310	0.05	0.26	0.24	0.24
2017	7787	802	433	0.03	0.25	0.25	0.24

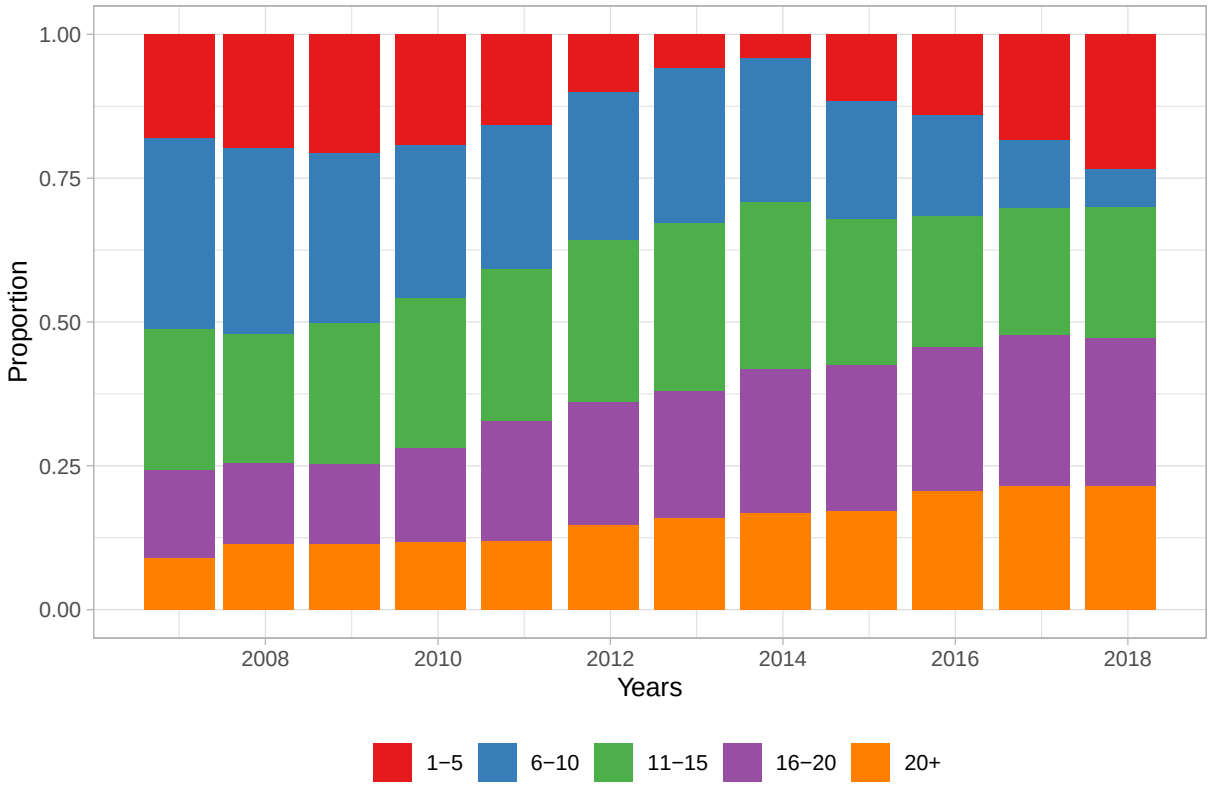
Notes: This table presents characteristics of CPD officers who have pay grade level "D1".

C.2 Officers Over Time

Figure C.1 displays the changing tenure composition of the force over the sample period. Despite the increasing retirements over time, the force has grown consistently older between 2007 and 2017. Accounting for 25% of the force in 2007, officers with more than 15 years of experience represent 35% of the sample in 2017. While the 11-15 years group has remained roughly constant at about one-fourth of the force, the lack of recruitment in the early 2010s has led to a lower share of lower-experience (at most ten years) officers in the 2017 sample.

[40] About 8% of teachers move to another school each year according to the National Center for Education Statistics. See https://www.scilearn.com/teacher-turnover/.

Figure C.1: Dynamics of Tenure



Notes: This figure displays the changing tenure composition of CPD officers over time.

Table 7: Characteristics of the Districts Before and After a Move

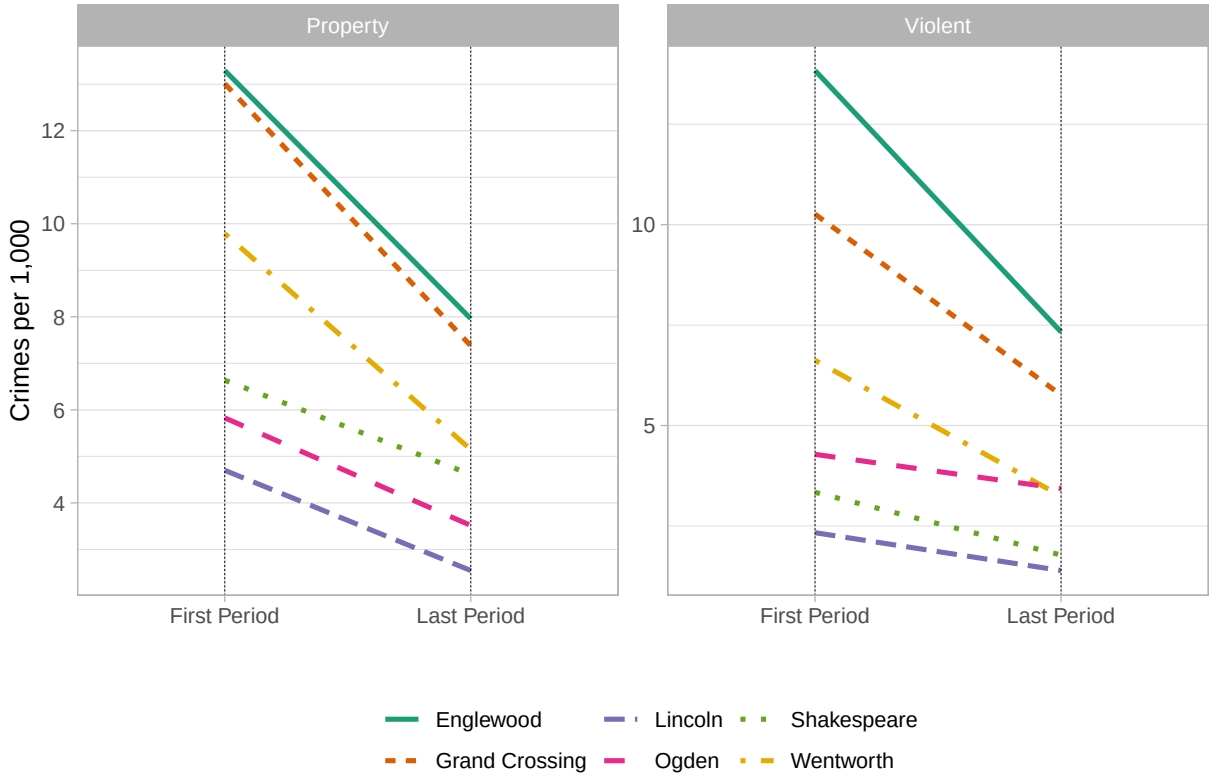
Mobility Status	Property Crimes		Violent Crimes	
	Before	After	Before	After
No	0.00610	0.00609	0.00384	0.00383
Yes	0.00617	0.00631	0.00429	0.00398

Notes: This table reports property crime rates and violent crime rates before and after a move.

C.3 The Dynamics of Crime

Then, we consider how crime has changed in Chicago over the same period. Figure C.2 displays the linear trends of crime rates over the sample period for a subset of districts (neighborhoods) in Chicago. The figure shows that while crime decreases everywhere, the declines have been most significant in the more violent neighborhoods. Thus, while crime has been declining in all districts, these changes have generally preserved the relative ranking of violent crime rates, which is important for the simulated IV.

Figure C.2: Dynamics of Crime



Notes: This figure displays the linear crime rate trends over the sample period for a subset of districts.

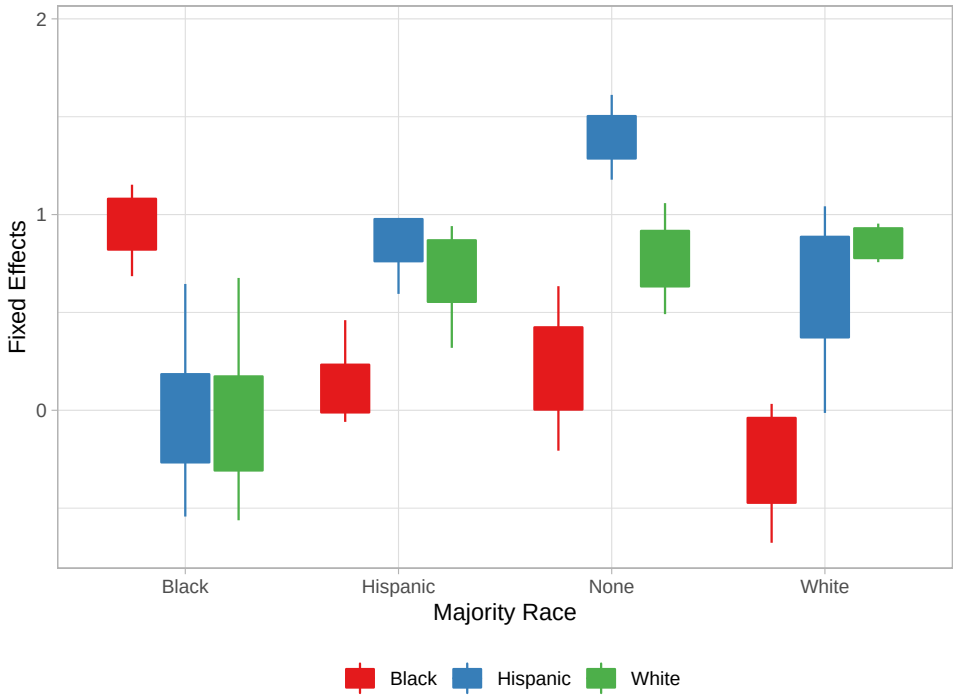
D Additional Figures

Table 8: Number of Moves

Mobilities	All	Black	Hisp.	White
0	0.68	0.68	0.68	0.67
1	0.21	0.21	0.21	0.22
2	0.07	0.07	0.06	0.07
2+	0.04	0.03	0.04	0.04

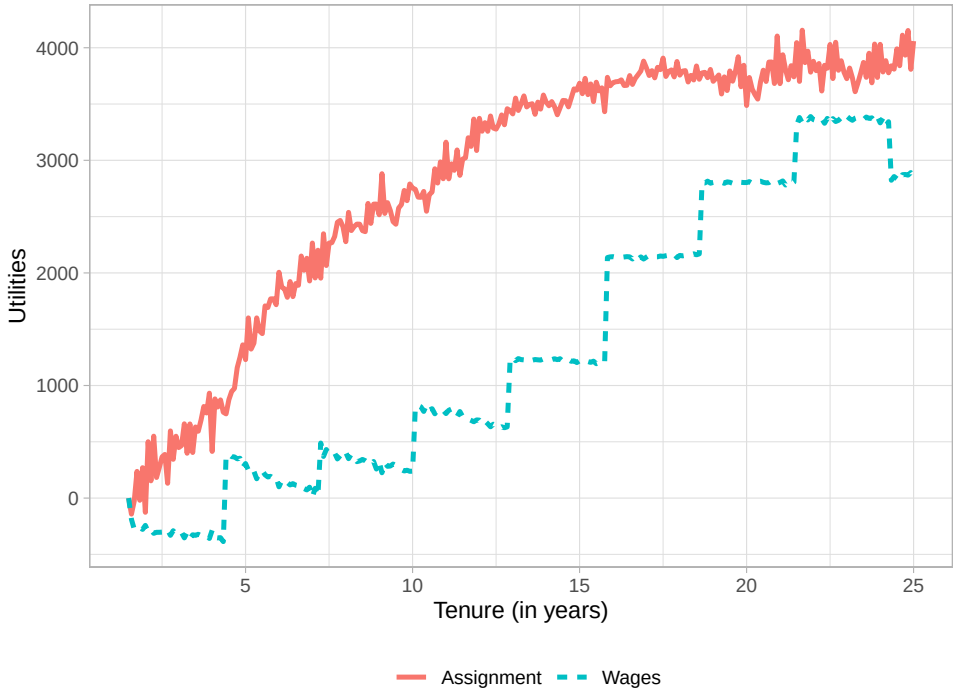
Notes: This table lists the share of officers by officer race and the number of total moves during the sample period.

Figure D.1: Fixed Effects Estimates by Residential Racial Composition



Notes: This box plot depicts district fixed effects by officer race. Boxes represent the 25th and 75th percentile, while whiskers represent the min and max.

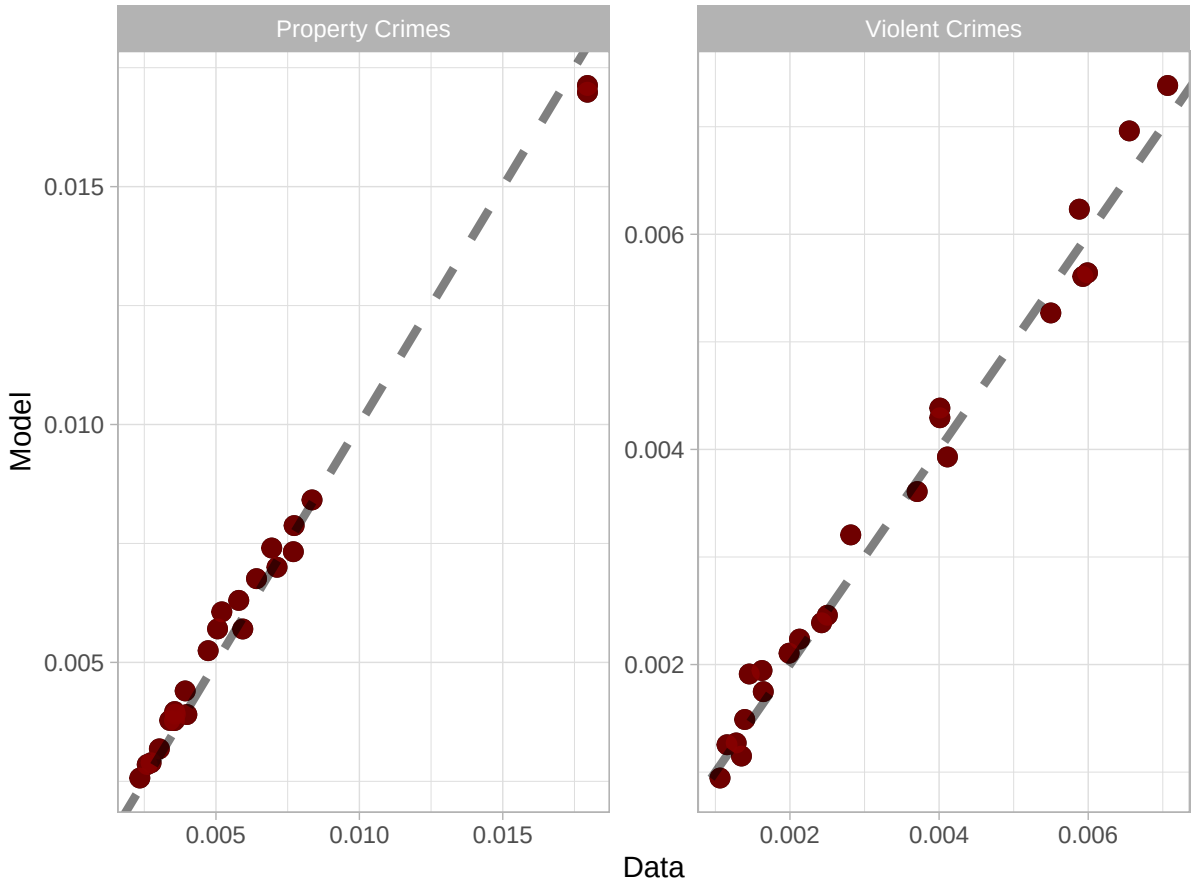
Figure D.2: Utility Decomposition



Notes: This figure displays the wage schedule and normalized officer utility by officer tenure. The wage schedule set forth in the CBA ensures that officers receive higher wages as they gain more experience, as evidenced by the blue step-wise pattern. However, the steeper red line makes clear that officers also receive a sizeable non-pecuniary benefit from the ability to transfer to more preferable districts as they gain seniority.

E Fit

Figure E.1: Crime Production Function Fit (Simulated IV)



Notes: This figures displays the fit of the simulated IV. The gray dashed line is a 45-degree line.

F Verification of Calendar System

In this section, we provide additional tests for whether the CPD rotational calendar is actually abided by in practice and that the composition of officers on a specific day is not driven by self selection patterns which would bias our identification of more tenured officers could choose not to work on days they believe to be high crime on short notice.

There are multiple ways to test the validity of the calendar assignment system. First, ignoring the rotations with 3-day weekend rules (much less common than 4-2 DOGs), vacation days, etc., most officers officers work 4 of every 6 days. In line with this, the likelihood an officer in the data who is working on a specific day of the week is working on that day of the week next week is 67% (65% for officers working as beat officers on a given day). Second, the 4-2 schedule is by far the most common working pattern in the data: 54% of observations in the data belong to a 4-2 spell alone, with the next most common being 5-2 and 4-3 spells (at 7% and 3% respectively).

We test for violations of this system, ensuring that the calendar is abided by in practice, and more experienced officers cannot induce variations away from this schedule or self-select in and out of working certain days or shifts.

Table 9: Verification of Calendar System

	DoW Next Week		N. Days	Start Hr.	End Hr.	Watch Dur.
	(1)	(2)	(3)	(4)	(5)	(6)
(Intercept)	0.645***	0.540***				
	(0.000)	(0.001)				
Tenure	0.002***	0.000***	−0.005***	−0.035***	0.052***	−0.003***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Mean DV	0.673	0.545	15.9	13.5	11.7	8.95
N Obs.	8354098	3258457	528803	8421366	8421366	8421366
FE			YM	Watch	Watch	Watch
Level:	PO-Day	PO-Day, Beat PO	PO-YM	PO-Day	PO-Day	PO-Day
R^2 (proj model)	0.001	0.000	0.000	0.018	0.002	0.003

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Notes: This table displays the associations between officer tenure and various outcomes related to working schedule and duration using the daily assignment data. Column (1) and (2) display the effect of tenure on the likelihood of working the following week on a given day conditional on working that day in the current week (e.g., if the officer worked this Monday, the likelihood they will work the next Monday). Column (1) is for all police officers, and Column (2) is for officers working a beat officers on a given day. Column (3) is at the officer-year-month level and the outcome is the number of days an officer works in given month, including year-month fixed effects; Columns (4)-(6) are at the officer-day level with watch (shift) fixed effects to correct for fixed differences, and the outcomes are starting hour, ending hour, and watch (shift) duration.

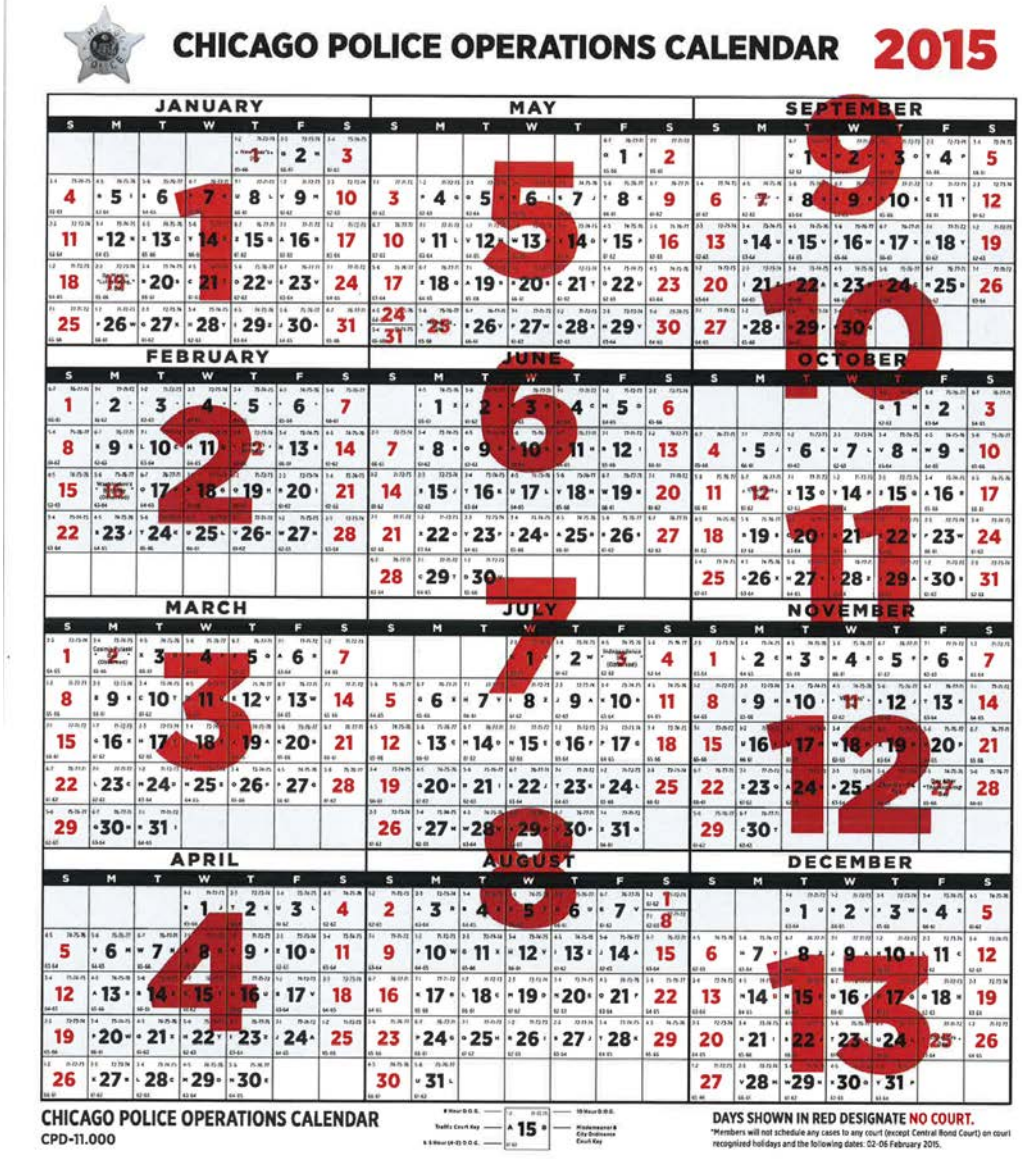
Table 9 displays various regressions testing the calendar's implications. Our main assumption is that if officers could select out of working on specific days and this was related to seniority, then tenure should be related to deviations from the calendar system.

Column (1) displays a regression of officer tenure on the likelihood of working the following day of week (e.g., working next Monday given the officer worked this Monday). The coefficient on tenure is 0.3% of the intercept, and the $R^2 = 0.0009$. Column (2) displays the same but only for shifts as beat officers (e.g., likelihood of working as a beat officer the next Monday given working as a

beat officer this Monday), and the coefficient is 0.01% of the intercept with $R^2 = 0.00003$. Essentially, tenure has no economically significant relationship with deviations from the main 4-2 pattern for all officers and those working as beat officers on a given day. Column (3) displays a regression of tenure on the number of days an officer works in a month; again, tenure has an economically insignificant effect and explains virtually none of the variation.

Though tenured officers still abide by the schedules and rotation, and thus cannot select their working days based on short-run crime trends, we may be concerned, however, that more tenured officers are able to choose how long or what times the work regardless of their watch assignment and DOG. Columns (4)-(6) display the results of regressions of tenure on start hour, end hour, and duration. Overall, tenure has an economically insignificant effect on each of these outcomes.

Figure F.1: 2015 CPD Operations Calendar



G First experience

In this section, we document whether PO who are initially assigned to more violent district are more deterrent than the other officers. We use the same MDSB specification, additionally controlling for the effect of first assignment in the most violent districts (6,7 and 11).

We also test to see if officers whose first geographical units had high violent crime are more likely to be promoted or served in a special unit later on. While this is not a perfect test for the effect of experience with violent crime on career trajectory, it will help us determine if one's starting unit is of first order concern or likely to be related to selection on officer unobservables. Table 10 displays the results of regressing whether or not the officer is ever in a special (non-geographic and non-academy) unit (Columns (1) and (2)) or ever promoted beyond D1 ((Columns (3) and (4))on their first unit being high crime (6, 7, or 11), with even columns containing officer demographic controls. The sample includes all officers after 2000 and those for whom a first geographic unit was identified (N=8641). The results show that while race and gender are related to career trajectory, one's first geographic unit being high crime is largely unrelated.

Table 10: Effect of First Assignment on Promotion

	Special Unit		Promotion (Non-D1)	
	(1)	(2)	(3)	(4)
First Unit = High Crime	0.015	0.016	0.016	0.017
	(0.01)	(0.01)	(0.013)	(0.013)
Black		-0.054**		-0.042***
		(0.018)		(0.014)
Hispanic		-0.047***		-0.025**
		(0.014)		(0.011)
Male		0.024*		0.014*
		(0.013)		(0.007)
Mean DV	0.14	0.14	0.101	0.101
Number of Observations	7221	7173	7221	7173

Notes: This table displays the association between an officer's career advancement and whether their first geographic unit assignment was in a high crime district. High crime districts are defined as districts 5, 6, and 11. The outcome variables are whether the officer was ever in a non-training and non-geographic district ('Special Unit') (columns (1) and (2)) and whether the officer was ever promoted past the most common and initial rank of D1 (e.g., to detective, sergeant, etc.) (columns (3) and (4)). Even columns contain controls for whether the officer is Black, Hispanic, or Male. All specifications include start-year fixed effects. Standard errors clustered at the start year level are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.

Table 11: Effect of First Assignment on Crimes

	Violent Crimes			Property Crimes		
	(1)	(2)	(3)	(4)	(5)	(6)
Share Tenure = [5,10)	-2.103***	0.607	-0.712	5.678***	4.868***	-0.613
	(0.171)	(0.991)	(0.581)	(0.287)	(0.303)	(0.601)
Share Tenure = [10,15)	-14.449***	-4.826**	-0.797*	1.642***	-6.509***	-0.956
	(0.189)	(2.214)	(0.432)	(0.319)	(0.474)	(0.614)
Share Tenure = [15,20)	-14.37***	-3.808*	-1.455***	-3.909***	-5.078***	0.745
	(0.22)	(1.907)	(0.5)	(0.37)	(0.503)	(0.747)
Share Tenure = 20+	-10.289***	-3.394	-1.126*	6.787***	-2.755***	2.342**
	(0.309)	(3.097)	(0.648)	(0.519)	(0.667)	(0.971)
Share First Unit HC x Tenure = [5,10)	3.876***	0.562	-1.804	-1.772***	0.045***	-0.005
	(0.276)	(3.371)	(1.954)	(0.465)	(0.003)	(0.005)
Share First Unit HC x Tenure = [10,15)	-0.731	0.076	1.399	-18.216***	7.759***	-0.83
	(0.501)	(3.63)	(1.692)	(0.844)	(0.56)	(0.59)
Share First Unit HC x Tenure = [15,20)	-6.982***	-0.662	1.193	1.786*	0.317	-0.515
	(0.641)	(3.489)	(1.033)	(1.078)	(0.524)	(0.544)
Share First Unit HC x Tenure = 20+	-2.819***	3.267	0.663	28.398***	1.165**	0.54
	(0.879)	(5.77)	(1.366)	(1.479)	(0.576)	(0.523)
Mean DV	10.516	10.516	10.516	17.786	17.786	17.786
Number of Observations	66745	66745	66745	66745	66745	66745
Controls	X	X	X	X	X	X
District (D)		X			X	
Month-Year-Day-District (MDD)			X			X

Notes: This table displays the effect of beat officer tenure and the share of beat officers who started in high crime units on the number of violent (Columns (1)-(3)) and property crimes (Columns (4)-(6)) reported on a day within a geographic district. Tenure shares are computed as the share of beat officers (relief and non-relief) who reported working in a given unit on that day at any time, and whether an officer was in a high crime unit is determined by whether they served in districts 5, 6, or 11 as their first geographic unit assignment. The excluded group is the share of officers with less than 5 years of experience, and probationary officers (less than 1.5 years) are excluded from the data. Controls include the number of beat officers and the shares of Black, Hispanic, and female beat officers. Day fixed effects refer to the day of the week. Standard errors clustered at the MDD level are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.