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POLICE OFFICER ASSIGNMENT AND NEIGHBORHOOD CRIME

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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. We document that the current bidding process, which grants priority based on seniority, results in the assignment of more experienced officers to less violent and high-income neighborhoods. Our empirical model combines estimates of heterogeneous officer preferences underlying the bidding process with causal estimates of the effects of officer experience on neighborhood crime. Equalizing officer seniority across districts would reduce violent crime rate by 4.6 percent and significantly decrease inequality in crime, discretionary arrests, and officer use of force across neighborhoods. Moreover, this assignment can be achieved in a revenue-neutral way while resulting in small welfare gains for police officers, implying that it is more equitable and efficient.

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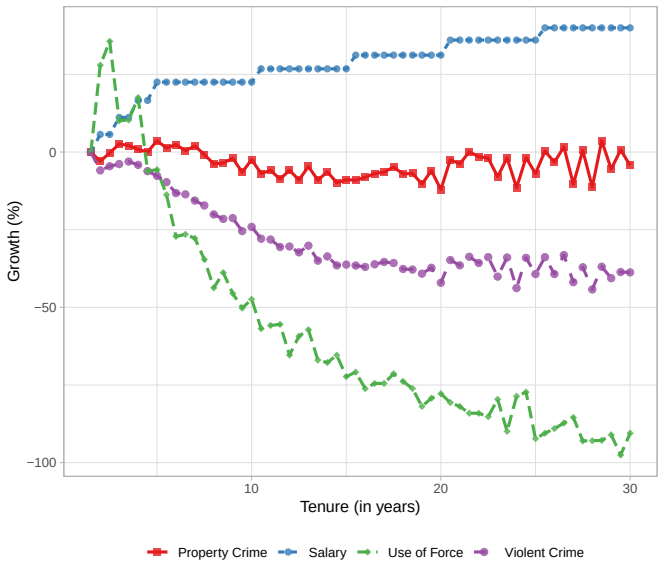
"One of the challenges for police is that the people dealing with the public are often your most inexperienced workers, the people who have the least experience in policing. It's the person with one, two years on the job who is dealing with the customer."

Philip Banks III, Former NYPD Chief of Police (The Black and the Blue, pg. 207)

Introduction

In many 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.

Figure 1: Dynamics of wages and assignments



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.

This equilibrium allocation 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. And the assignment of more experienced (and more expensive) officers to higher-income, predominantly white neighborhoods may lead to significant inequities not only related to the effectiveness of policing but also to police interactions with civilians. The green line in Figure 1, in particular, shows how sharply officer use of force declines with experience.

[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.

In this paper, we develop an empirical model of the bidding process which 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 2007-2017, which provide 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.

Ultimately, two sets of parameters are critical for determining potential efficiency and equity losses in a seniority-based mechanism: (i) the strength of officer preferences to work in safer neighborhoods (which can be increasingly actualized as officers gain seniority) and (ii) the returns to officer experience in the prevention of neighborhood crime and other outcomes related to police-civilian interactions (e.g., discretionary arrests, police use of force). Estimating the second set of key parameters—the causal impact of officer seniority on crime and police-civilian interactions—requires dealing with the systematic selection of more senior officers into safer neighborhoods. Failing to do so would naturally lead to an overstatement of the returns to officer experience.

To identify a neighborhood crime production function, we develop a research design 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 driven by endogenous officer responses to district-level changes in crime patterns or other factors over the study period.

The resulting simulated IV estimates imply a significant causal impact of officer seniority on neighborhood crime, but 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.

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).[2]

We first show that equalizing officer seniority across districts would reduce the overall violent

[2]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 disticts, for example, inexperienced white officers are replaced by more senior Black officers in the equitable allocation counterfactual.

crime rate in Chicago by 4.6 percent, while having a negligible effect on the overall property crime rate. The allocation of officers under this alternative is more efficient as the significant reduction in violent crime is achieved without diverting any additional public resources toward policing. In addition, there is a small *increase* in the overall welfare of police officers: some police officers gain and others lose welfare under the alternative design, but the net effect is negligible because total officer pay is constant. The new equilibrium simply exchanges officers between districts.[3] This more efficient allocation has important equity implications as well: the inequality in exposure to violent crime rates across police districts decreases. More precisely, the spatial variability in crime declines by over 10 percent, as violent crime falls sharply in the highest crime and poorest districts.[4]

In order to better understand how experienced officers deter crime and behave differently from their junior counterparts, we perform an individual-level analysis on officers' daily activities, building off Ba et al. (2021). We use detailed fixed effects that capture daily shift and beat assignments to compare officers working in the same circumstances and environment. 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 slightly fewer violent crime arrests. Putting all of the results together, more experienced officers appear to deter violent crime while making fewer low-level arrests and using less force.

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 crucial pieces of 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). 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).[5]

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

[3] As we explain in more detail below, officers actually gain a small amount of welfare, on average, under our equitable assignment mechanism because officers with strong idiosyncratic preferences are better able to satisfy their preferences early in their careers.

[4] In a previous version, we also implemented an alternative policy that assigns officers to minimize aggregate violent crime. As results under this policy are similar to those where tenure is equalized across districts, we focus on the allocation that equalizes tenure across districts.

[5] 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. Doctors are incentivized to practice in underserved areas in the US using "Health Professional Shortage Area" payment bonuses. See HPSAP program.

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.[6] 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; 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).[7] We document that experienced officers prevent crime without increasing the intensity of arrests for minor infractions.[8] 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 develops the empirical model of assignment, and the estimation strategy is detailed in Section 3. Estimation results are presented in Section 4 and counterfactual analyses are discussed in Section 5. Finally, Section 6 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 (CPD) for two main reasons. First, we have been able to assemble unusally detailed data on police officers and their assignments to districts, beats, and shifts in Chicago over a long study period, 2007-2017.[9] Second, the mechanism used to assign officers to districts in Chicago is straightforward, well understood by officers, and followed rigorously in practice.

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 who are assigned to units. The city is currently divided into 22 geographical police districts managed by commanders who supervise about 65% of the entire CPD.[10] The remaining officers are assigned to specialized

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

[7] Chalfin and McCrary (2017) provides an extensive review of the literature on criminal deterrence. Also, see Di Tella and Schargrodsky (2004); Draca et al. (2011); Blanes i Vidal and Kirchmaier (2017); Weisburd (2019).

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

[9] Shift and beat data exist in high quality for 2010-2017.

[10] Figure B.1 in the 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, and

units (including detectives, canine, marine, helicopter, civil rights, etc.).

1.1.1 Assignment Mechanism

For the first 18 months of their career, 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 avalaible 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 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 muct 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.

1.2 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, salary, daily shift and beat assignment histories, arrests, and incidents of use of force.[11]

We supplement our Chicago police dataset with crime data at the district level. A primary outcome for our analysis is the district crime rate, 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 B.2 in Appendix B documents the geographic distribution of crime in the city of Chicago.

1.3 Descriptive Evidence

In the 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

during 2012, 3 small districts were absorbed into largers ones, leaving 22.

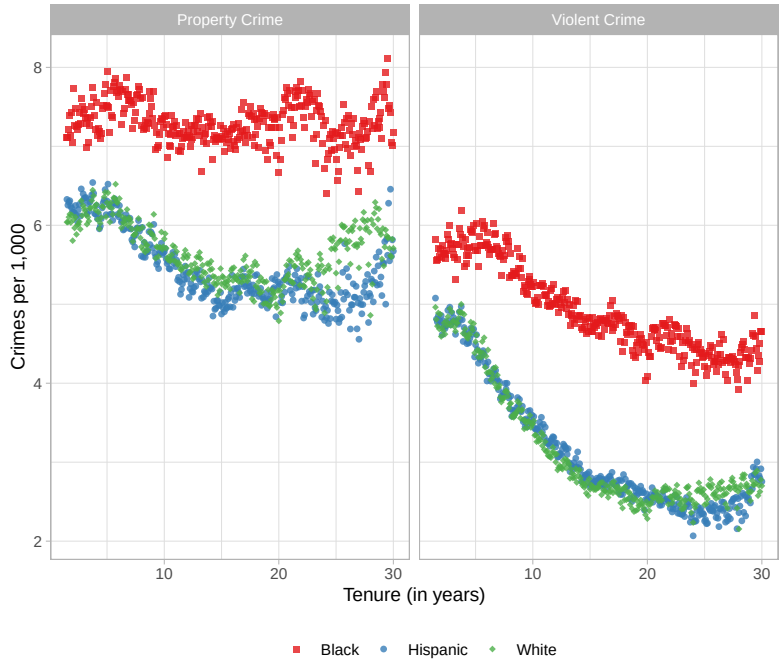
[11] The precise steps to derive our final sample are provided in Appendix A.2 and A.3.

neighborhoods with initially higher levels of violent crime.[12] 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 primaily 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.[13] However, the decline in violent crime rates are significantly larger for White and Hispanic officers relative to Black officers.

Figure 2: Assignment of Police Officers



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.

[12] 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.

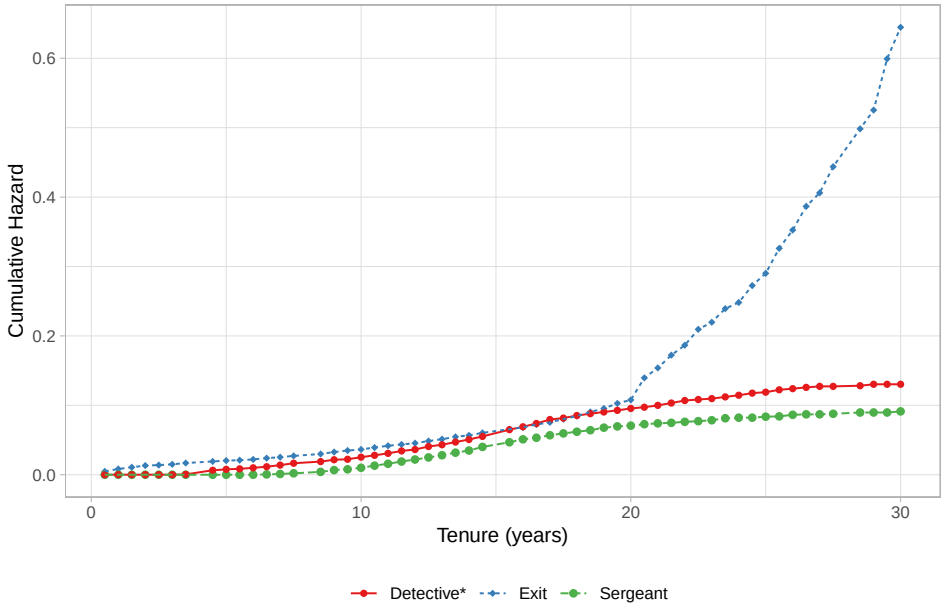
[13] The combination of the increase in average officer experience level and the fall in violent crime rates over our study period also contributes a small amount to this observed pattern.

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.

Figure 3: Promotions and Exits



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

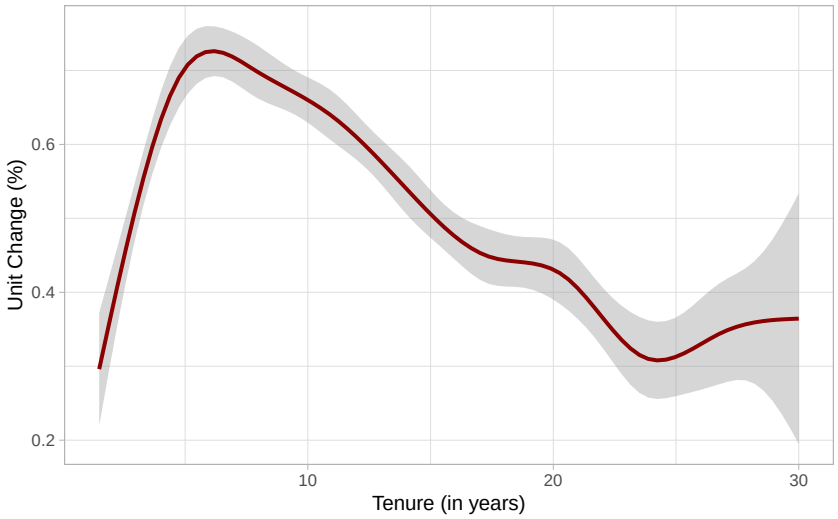
The annual hazard rates for all of these career transitions are very low. By 20 years of experience less than 10% of officers have been promoted to sergeant or detective. And only about 10% of officers exit the CPD before 20 years of experience. At 20 years of tenure, the slope of the exit rate begins 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.[14]

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

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

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: Transition rates over tenure



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 5 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 does not change district 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 changes districts more than twice.

2 An Empirical Model of Police Assignment and Crime

In this section, we construct and estimate a model of mobility for police officers, as governed by the seniority-based bidding process. We quantify which preference components explain the mobility of officers across geographical units and whether more experienced officers have a higher deterrent effect on crime.

2.1 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 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 capture the priorities built into it.

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, $\succ_\mathrm{d}$, as follows. If an officer i is assigned to district* d *in period $t-1$, while officer i' is not, then $i \succ_\mathrm{d} i'$ even if $\tau_i < \tau_{i'}$. Otherwise, $i \succ_\mathrm{d} i'$ 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*

$$d \succ d' \quad \forall \quad \boldsymbol{c}_d \gtrless \boldsymbol{c}_{d'} \,. \tag{1}$$

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

$$\boldsymbol{m}_\mu(d) \gtrless \boldsymbol{m}_\mu(d') \,. \tag{2}$$

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.

2.2 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.[15]

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 x, crime in the district c, and other district attributes z. Police officers are heterogeneous in observed attributes 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 z (e.g., racial/ethnic composition of the population and police force), and crime rates c. The utility function is specified as:

$$\begin{aligned} v_{idt} &= v(x_{it}, c_{dt-1}, z_{dt-1}, \delta_d, \epsilon_{idt}) + w_d(\tau_{it}), \\ v_{i0} &= 0 \text{.} \end{aligned} \tag{3}$$

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.

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:[16]

$$v_{i\ell t} > v_{idt} \quad \forall \quad d \in \mathcal{D} \text{.} \tag{4}$$

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.

[15] In characterizing the problem as a sequence of static decisions, we implicitly assume that there are no adjustment costs between districts.

[16] 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.

2.3 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

$$c_{dt} = m(\tau_{dt}, z_{dt}, \psi_{dt}, \xi_{dt}) \cdot \tag{5}$$

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.[17]

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 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.

3 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.

[17] A key 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 believe this to be a reasonable first-order approximation because even low-crime districts are internally heterogeneous and officers are exposed to crime in all parts of the city (see the Chicago Crime Map). Theoretically, it is not clear ex ante that being exposed to high levels of violent crime early on in one's career improves an officer's ability to deter crime or to interact with civilians; this question is ground for future research.

3.1 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

$$P_\theta^{\mathbf{m}}(y_{dl}|\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{c}) = \int P_\theta(\boldsymbol{v}_{il}(\theta) > \boldsymbol{v}_{id}(\theta)) \times P_\theta(\tau_i > \max(\tau^\star_{-i}))\,\blacksquare \tag{6}$$

where $\boldsymbol{v}_\theta$ is the utility evaluated under parameter values θ, $\tau^\star_{-i}$ 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. We use the *stability* property of the assignment mechanism to estimate the preferences of officers.[18] 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 inequality conditions:

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

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: $\boldsymbol{v}_{idt} > \boldsymbol{v}_{id't}$ if $\tau_{it} > \underline{\tau}_{dt}\blacksquare$.

These moment inequality 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

[18] In a previous version, we use simulation methods to estimate preferences. This intuition is based on the observation that while a probabilistic approach to estimating the probability of submitting the winning bid may be complex, one can easily derive it through simulations. A simple algorithm with the following steps

- For a guess of $\boldsymbol{\theta}$, at period t, simulate utilities under a parametric assumption for $v(\cdot)$ for all individuals.
- Given $v(\cdot)$, and a number of vacancies, officers bid for positions.
- Bidding outcomes are realized, and mobility patterns are realized.

More precisely, for any set of parameters, and any draw from the stochastic component, we calculate the indirect utility of all officers in all districts for the district with a vacancy and for their current district. We then solve for which officers submit bids and the identity of the most senior bidder. Results were similar.

provided by the data on filled vacancies. In total, there are 3,739,546 moment conditions.

To facilitate the analysis, we make parametric assumptions that guarantee that preference parameters are point-identified. The utility function is additive and separable:

$$v_{idt} = \alpha_c c_{dt-1} + \beta_c x_i c_{dt-1} + \delta_d + \epsilon_{idt} \cdot \tag{7}$$

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

$$\epsilon_{idt} \sim \mathcal{N}(0, \sigma_\epsilon^2) \cdot \tag{8}$$

where the error term ϵ_{idt} is independent across officers, districts, and time; additionally, the unobserved district effects δ_d are assumed fixed.[19] 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.

3.2 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:

$$c_{dt} = m(\tau_{dt}, z_{dt}, \psi_{dt}, \xi_{dt}) \cdot \tag{9}$$

where, again, τ_{dt} is a set of statistics characterizing the experience of officers in the district. The main challenge in estimating equation 9 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.

The inclusion of district fixed effects in equation 9 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

[19] 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.

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.[20] In our empirical application, we specify crime production function as a log-linear function:

$$\log c_{dt} = \gamma_0 + \gamma_\tau \tau_{dt} + \gamma_z z_{dt} + \psi^{(0)}_{d} + \psi^{(1)}_{t} + \xi_{dt}\,. \tag{10}$$

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

3.3 Officer Level Analysis

Because crime rates are reported at the district-month level, our estimation of the neighborhood crime production function must be conducted at the district level. For an additional set of outcomes, including arrests and use of force, however, we are able to leverage the richness of the administrative datasets that we have assembled to examine the effect of experience at the level of the individual officer. In particular, we are able to match detailed daily data on officer deployment—i.e., the assignment of each officer to a beat (a small geographic region within the district) and shift (time of day)—to officer-level data on daily arrests and reported use of force (Ba et al., 2021; Rivera, 2021).[21]

As our goal is to compare officers of different seniority working in similar conditions, we exploit the quasi-experimental rotation in the CPD operations calendar. Specifically, officers are assigned to day-off groups late in the previous calendar year, and these groups determine who works on certain dates in the following year. As such, officers have very little discretion on this rotational schedule, mitigating threats from self-selection.[22]

Further, we follow an empirical strategy similar to Ba et al. (2021) and compare officers who are serving the same combination of month-year, day of the week, shift time, and assigned beat, or "MDSB" for short. MDSBs allow for comparisons of officers essentially working in the same place

[20] 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.

[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 2016 in the geographic units. The resulting daily panel contains over 6 million officer-day observations on almost 9,000 officers. Due to the filters, most notably the restricted time frame, this accounts for about 75% of officers in the main analyses. We supplement these data with adult arrests. An arrest is counted only for officers who are listed as primary or secondary officers on the arrest, and not assisting officers.

[22] See Ba et al. (2021) for more details on daily assignment schedules and rotations.

and time and, importantly, with the same opportunity to take enforcement action.[23] Formally, the outcome of an officer i assigned to MDSB j on day t is Y_{ijt}. We estimate the impact of tenure on Y_{ijt} as follows:

$$Y_{ijt} = \alpha_i + \gamma_j + \tau_{ijt} + \epsilon_{ijt} \text{▪} \tag{11}$$

where τ_{ijt} is the tenure of the officer i. In practice, we break the tenure variable into one-year buckets. The reference category is non-probationary officers with less than three years of experience, i.e., "new officers". As a consequence, our estimates are relative to the mean of new officers. Fixed effects for individual officers are denoted by α_i and for MDSB by γ_j.[24]

Our outcomes of interest are violent, property, and non-index crime arrests and officer use of force.[25] Officers' ability to arrest a potential suspect involved in an offense with an identifiable victim is captured by violent and property arrests. 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).

4 Results

4.1 Preferences Estimates

Table 1 presents estimates for officers' preferences over district-level crime rates (α_c and β_c in equation 7). 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.

[23] Moreover, observing the times and places of deployments allows us to include in our analysis officers with zero enforcement but present in an MDSB.

[24] 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.

[25] Violent and property crime categories include official index crimes and related non-index crimes. While non-index refers to all other non-index crimes.

Table 1: Officer's preference 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.

4.2 Estimates of Officer Experience on Crime

Table 2 presents estimates of the impact of officer tenure on district crime rates (γ_τ in equation 10).[26] Panel A reports estimates for violent crime, and Panel B reports estimates for property crime. Basic OLS estimates are in column 1. Column 2 includes controls for officer characteristics (share of Black and Hispanic officers), the number of officers, and district fixed effects. Finally, simulated IV estimates are in column 3.

The simple OLS estimates presented in column 1 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 and officer characteristics significantly reduces the magnitude of these estimates for both violent and property crimes, as shown in column 2.

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

Table 2: Impact of Officer Tenure on Crime Rates

	OLS		Sim IV
	(1)	(2)	(3)
Panel A: Violent Crime Rate			
Tenure (years):			
$[5-10)$	-0.499***	-0.034	-0.101**
	(0.1)	(0.042)	(0.045)
$[10-15)$	-2.756***	-0.467***	-0.191***
	(0.111)	(0.056)	(0.05)
$[15-20)$	-2.056***	-0.347***	-0.202***
	(0.116)	(0.07)	(0.048)
20+	-1.843***	0.137	-0.183***
	(0.153)	(0.093)	(0.047)
Panel B: Property Crime Rate			
Tenure (years):			
$[5-10)$	0.606***	0.232***	0.08*
	(0.094)	(0.043)	(0.041)
$[10-15)$	-0.616***	-0.278***	-0.071
	(0.122)	(0.06)	(0.044)
$[15-20)$	-0.784***	0.159**	0.033
	(0.119)	(0.07)	(0.046)
20+	0.883***	0.323***	-0.026
	(0.193)	(0.093)	(0.046)
Observations	2861	2861	2861
Controls		Yes	Yes

Notes: This table reports elasticities of 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. $^{***}p < 0.01$, $^{**}p < 0.05$,* $p < 0.1$.

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, column 3 reports the results of the simulated IV specification described in Section 3. These results indicate that a one percentage point increase in the share of officers with 5-10 years of experience reduces violent crime rates by 0.10 percent (and reducing the share of officers with less than 5 years of experience by an equivalent amount). 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.

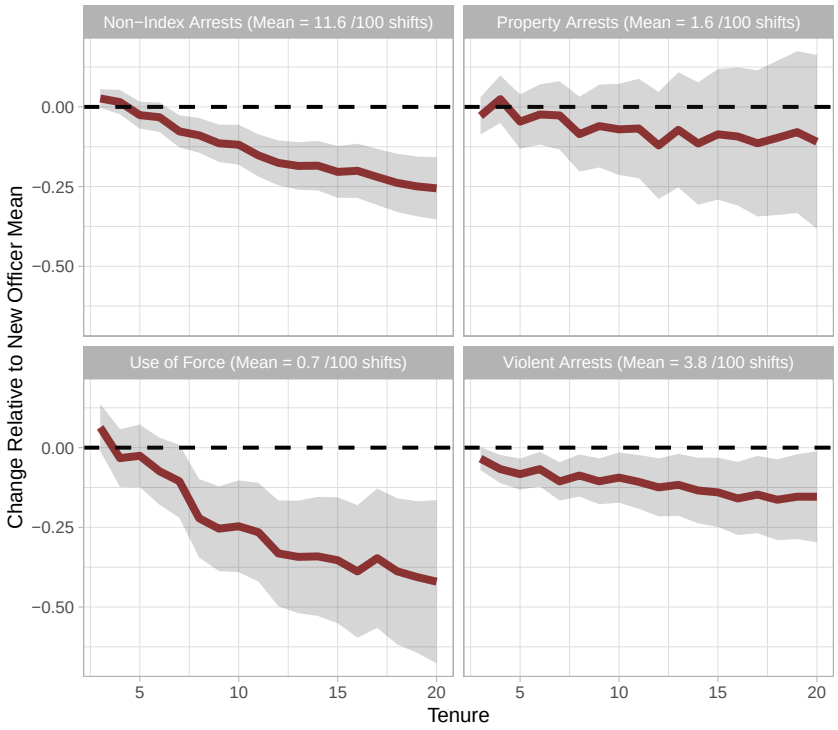
In summary, our results imply that increasing the share of more experienced officers in a district reduces violent crime, while having a negligible impact on property crime.

4.3 Officer Level Analysis

The previous results indicate that senior officers have a significant effect on violent crime, but provide little insight into the mechanisms behind it. Broadly speaking, we would like to know whether senior officers achieve these deterrence effects through more effective practices and community relationships, by deterring crime by resorting to questionable tactics such as the increased use of force or low-level arrests, or through incapacitation and high arrest counts.

In this section, we present results of an officer level analysis designed to provide some insight into how experience affects police tactics and interactions with civilians. As described in Section 3.3, this analysis is based on precise deployment data and exploits the quasi-experimental rotation in the CPD operations calendar, comparing officers who are working in the same combination of month-year, day of the week, shift time, and assigned beat or "MDSB" for short. Figure 5 displays the effect of officers' experience on the outcome of interests.

Figure 5: Effect on Tenure 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 3.8 violent, 1.6 property, 11.6 non-index arrests per 100 shifts and report using force about 0.7 times. Relative to these least experienced officers, our findings imply that arrests and use of force decline sharply with officer experience, while there is a negligible and imprecise effect of experience on property crime arrests and a relatively minor effect on violent crime arrests (a decline less than 0.5 arrests per 100 shifts). In this way, 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 that can reach 25% and 38%, respectively, relative to the mean of new officers.

We view our results as indicating that experienced officers are more effective at preventing violent crimes through deterring it; they do not appear to be incapacitating potential offenders through arrests, resorting to increased use of force on suspects, increasing reactive arrests, or increasing proactive (low-level) arrests. Together with the simulated IV results, these results also indicate that the impact of more experienced officers in reducing crime is accompanied by a reduction in arrests. As a consequence, arrests may be a misleading measure of police productivity (Mas, 2006; Prendergast, 2021). This is in line with findings in 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."

5 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.

5.1 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

$$\mu^{\ddagger} = \arg\min ||\sum_{j} \mathcal{T}(\mu_j^{\ddagger}) - \mathcal{T}|| \cdot \tag{12}$$

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:

$$\mathcal{W}^{\star} = \arg\min_{\mathcal{W}^{\star}} ||\mu(\Theta, \mathcal{W}^{\star}) - \mu|| \cdot \tag{13}$$

Under our specification of the utility function $v(\cdot)$, the share of officers in district d with experience level τ, $\mathcal{T}_d(\tau)$, is increasing with $\mathcal{W}_d(\tau)$. Brouwer's fixed-point theorem guarantees that a unique solution exists. We implement this method numerically, following the intuition for the fixed-point iteration: increasing the wage subsidy until it reaches the target allocation.

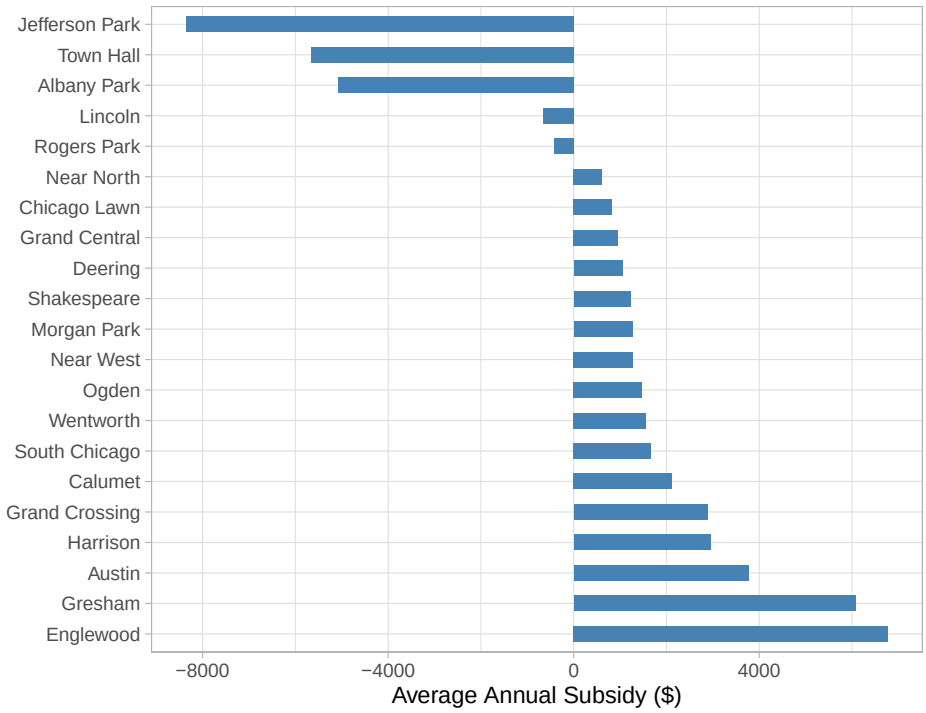
5.2 Results

5.2.1 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 mecha-

Figure 6: Average Subsidy by District



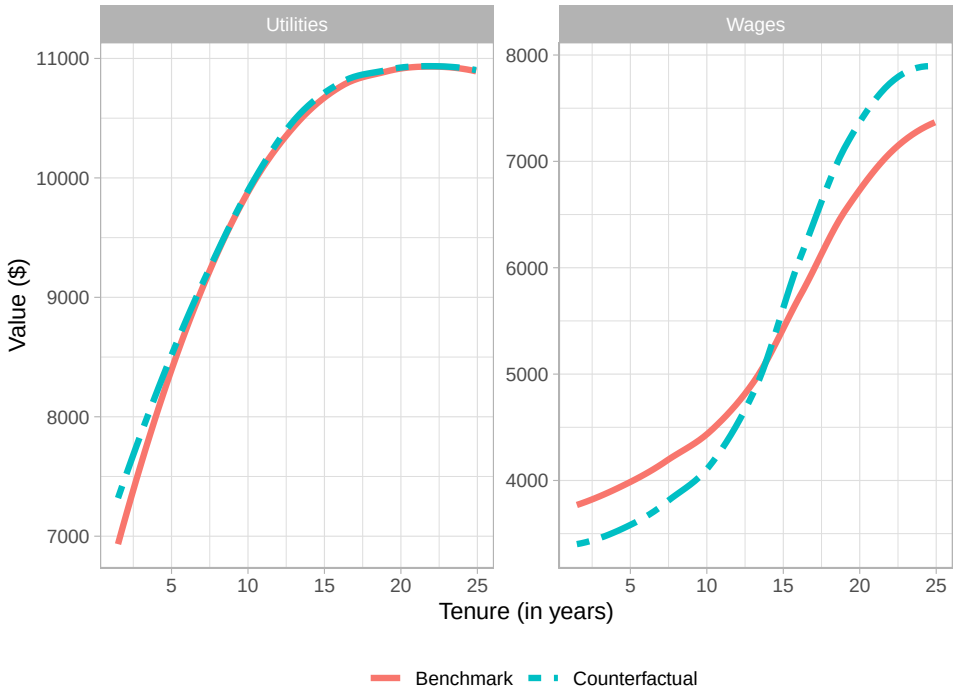
Notes: This figure depicts the average annual subsidy required to incentivize officers to transfer to that district. Districts are listed in increasing order of the subsidy amount.

nisms: (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 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

Figure 7: Utility and Wage Profiles



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.

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.[27] 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 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.[28]

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.[29]

[27] 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

[28] 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)).

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

5.2.2 Effects on Aggregate and Neighborhood Crime Rates

Table 3 shows the aggregate effects of the equity-based matching allocation on violent and property crime. As a benchmark, we report in column 1 the monthly number of crimes per 1,000 residents in Chicago, averaged over the full period (2007-2017). Column 2 reports the crime rates in the counterfactual assignment mechanism, which equalized officer tenure profiles across districts. Column 3 presents the percentage change relative to the benchmark.

Table 3: Aggregate Crime Effects

	Benchmark	Counterfactual	Change (%)
Panel A: Violent Crimes			
Average	4.819	4.596	-4.617
Max-min ratio	10.465	6.117	
Panel B: Property Crimes			
Average	7.277	7.281	0.05
Max-min ratio	6.204	6.846	

Notes: This table reports the aggregated effects of the equity-based matching allocation separately for violent crimes (Panel A) and property crimes (Panel B). Benchmark numbers report the average monthly number of crimes per 1,000 residents in Chicago averaged over 2007 and 2017. Max-min ratio is the ratio of the largest crime rate and the smallest crime rate. Counterfactual numbers report the crime rates in the counterfactual assignment mechanism. Change reports the percent change in per capita crime rates from moving from the benchmark to counterfactual assignment mechanism.

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.[30] 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.[31] 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, as shown in Section 4.3.

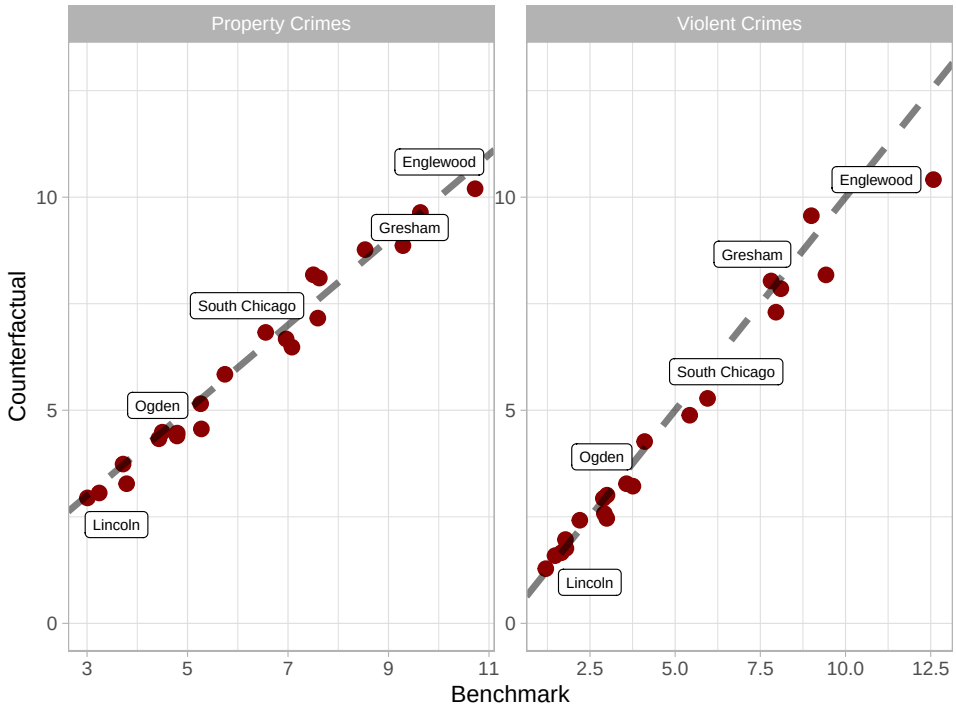
The aggregate reduction in Chicago's violent crime rate under the counterfactual comes about because, relative to the current equilibrium, more experienced officers are assigned to the districts with the highest violent crime rates. Thus, not surprisingly, the alternative assignment mechanism also induces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

[30] 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.

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

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



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 in Section 4.3, 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.

6 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, 2021), 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.

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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 2016. 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.[32]

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.

[32]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

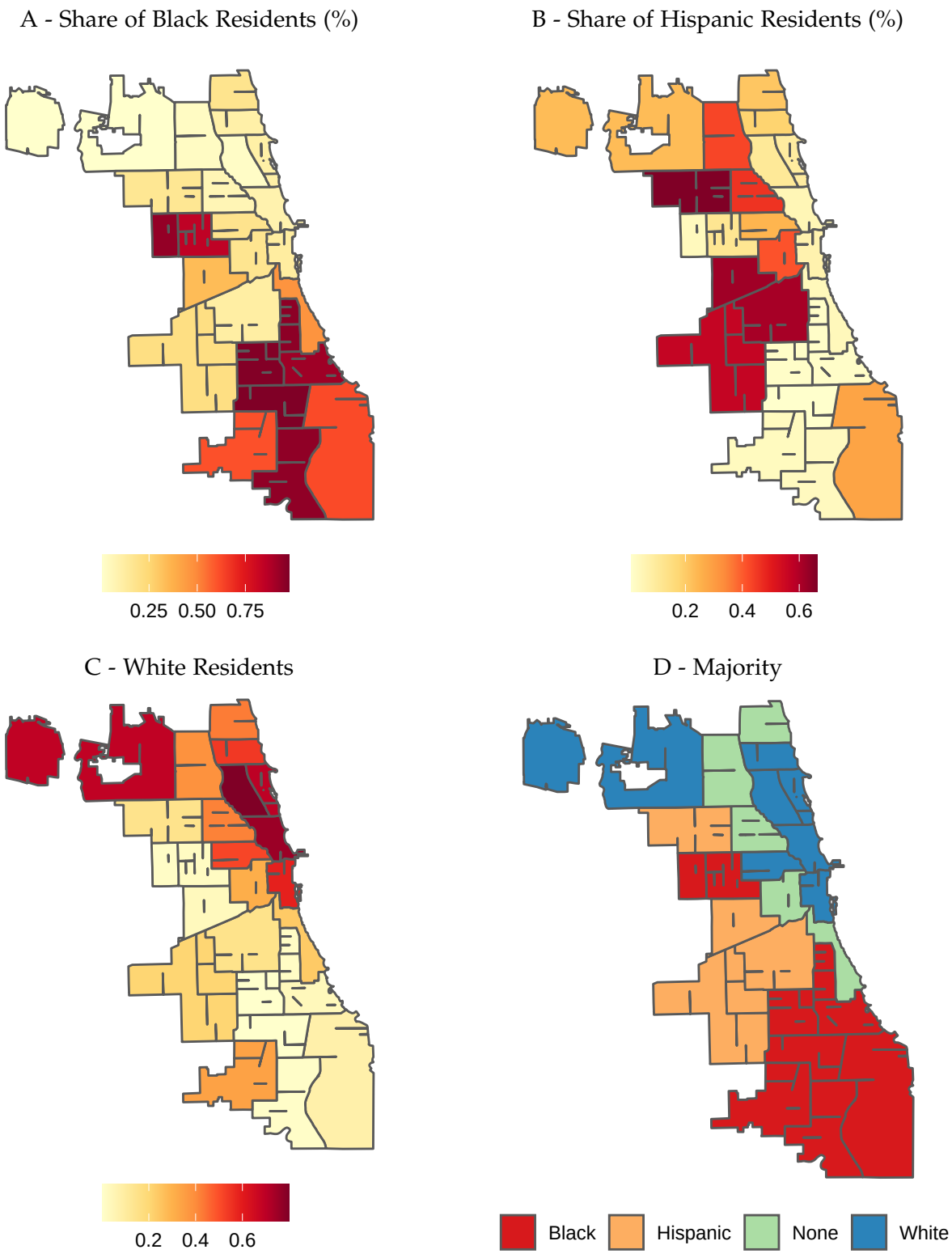
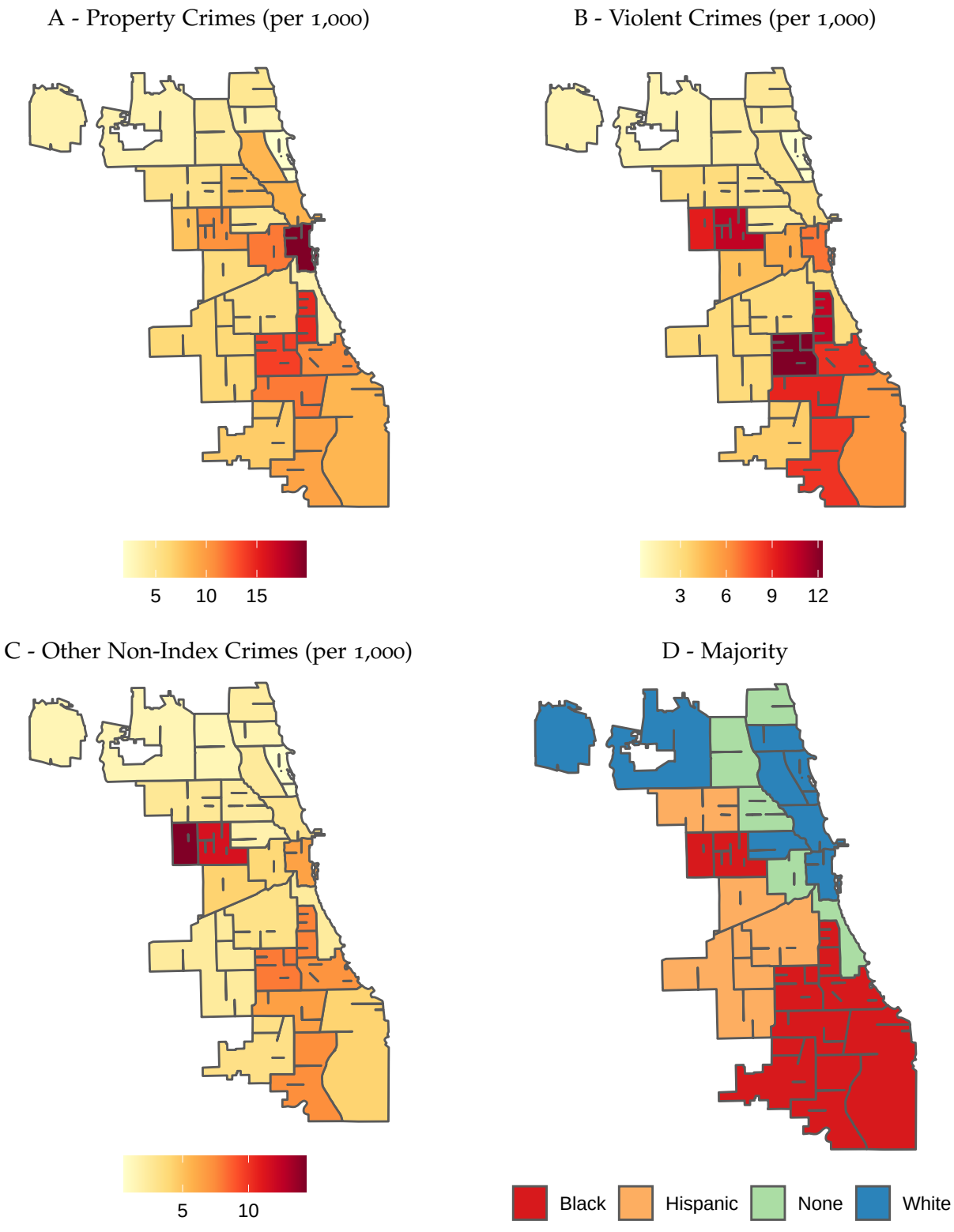


Figure B.2: Crime Segregation



C Description of the CPD

C.1 Police Force

Table 4 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.[33]

Table 4: 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: Police officers with pay grade D1 (i.e., a regular patrol or beat officer)

C.2 Officers Over Time

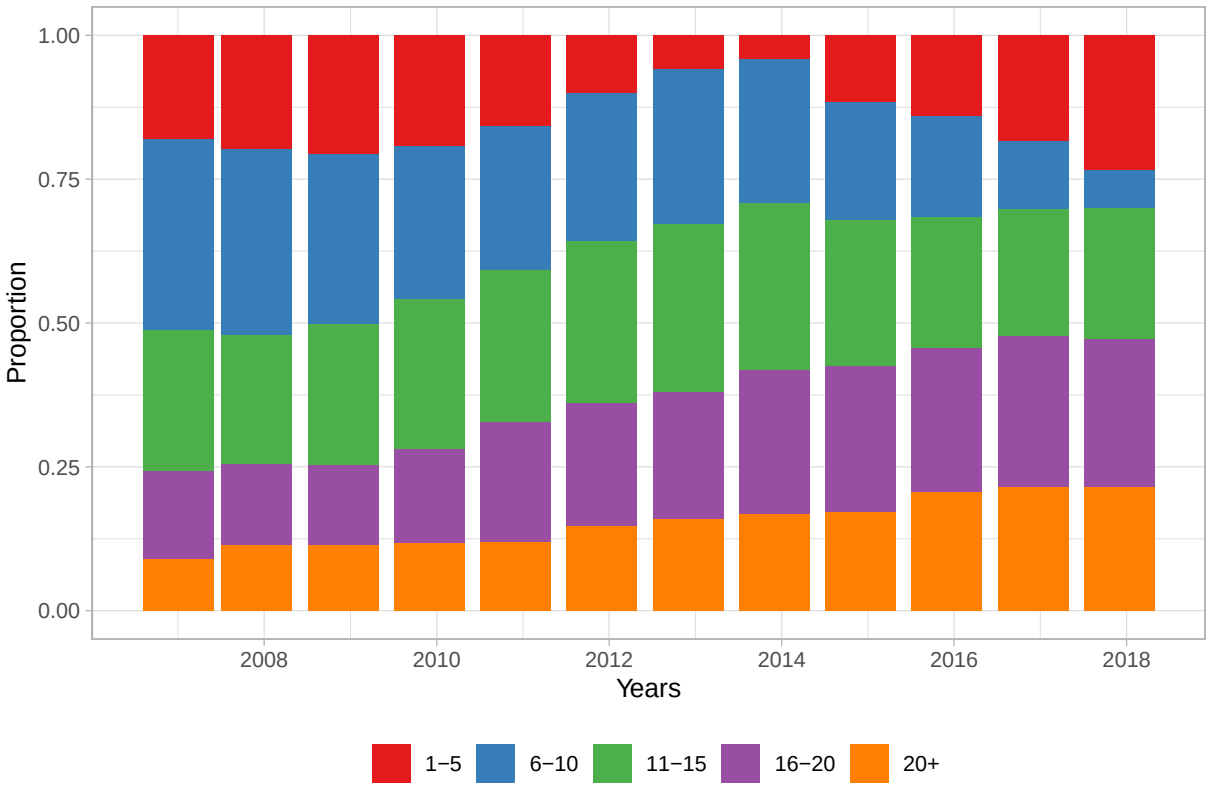
Figure C.1 displays the changing tenure composition of the force over the sample period. Despite the increasing retirements over time, the force has grown consistently older between 2007 and 2017. Accounting for 25% of the force in 2007, officers with more than 15 years of experience represent 35% of 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.

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

[33] 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



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.

D Additional Figures

Table 5: 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

Figure C.2: Dynamics of Crime

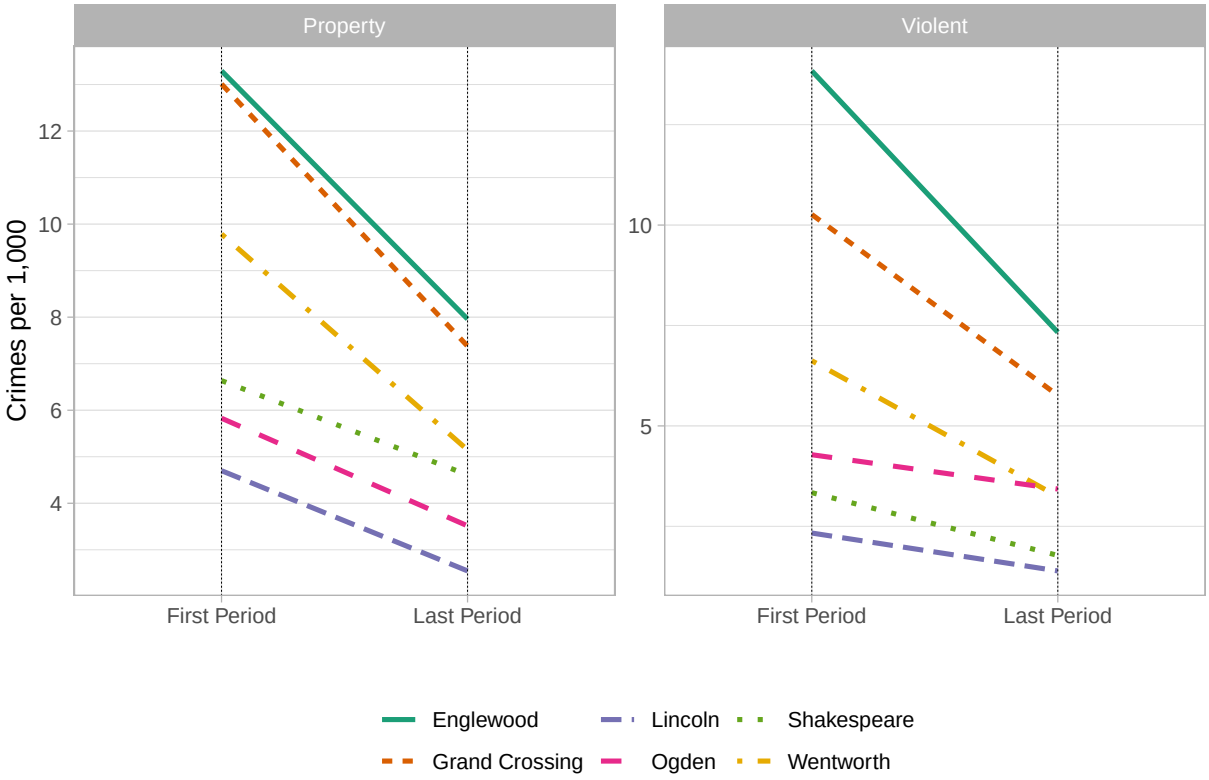
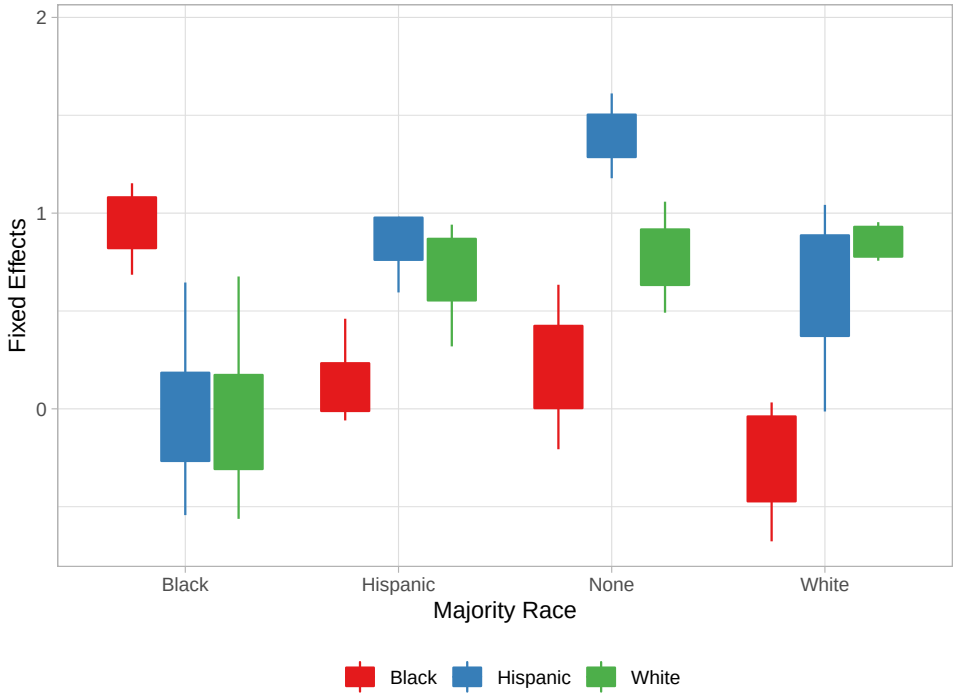


Figure D.1: Fixed Effects Estimates by Residential Racial Composition



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