The Wheel of (Over)Time

Jacob Kohlhepp* Robert McDonough†

July 15, 2025

Abstract

In the United States public sector, there are many examples where overtime is allocated informally, and overtime earnings are concentrated among a small number of government workers. Is this government inefficiency driven by insider influence, or an efficient reflection of worker preferences? We study the Los Angeles Department of Transportation, where a few traffic officers earned more than $100,000 in overtime over 1.5 years. A constantly rotating list called "the wheel" assigns overtime equally initially, but officers are allowed to informally trade. Using novel daily personnel records, we recover the position of the wheel as well as the time-varying network of potential relationships between officers. Officers are several times more likely to work overtime when they are well-connected to coworkers likely endowed with overtime. Nevertheless, overtime inequality primarily reflects underlying differences in preferences. Informal trading achieves 93.8% of the maximum possible allocative efficiency, or $4.15 million more than random assignment. This is because the cost of accessing overtime is low and the informal trade network is encoded with the overtime preferences of officers. As a result, replacing informal trading with formal auctions where officers bid wages has little impact on allocative efficiency, a modest 4.8% cost reduction for the government, and a 8.8% increase in overtime inequality.

Keywords: informal trade, auctions, overtime, networks
JEL codes: J22, M5

---

*UNC Chapel Hill Department of Economics. Contact: kohlhepp@unc.edu. We would like to specially acknowledge Michael Ludwig. His initiative and data assistance made this project possible. We are grateful for helpful comments from Peter Arcidiacono, Sungwoo Cho, Bo Cowgill, Marco Duarte, Luca Flabbi, Donna Gilleskie, Felipe Goncalves, Daniel Haanwinckel, Justin Hadad, Ingrid Hägele, Johnny Hyuhn, Maurizio Mazzocco, Canice Prendergast, Simon Quach, Kyle Woodward, Jon Williams.

†UNC Chapel Hill Department of Economics. Contact: robmcd@unc.edu.

1 Introduction

Public sector organizations in the United States are often accused of excessive and unequally distributed overtime, with news articles reporting examples of government workers making tens and sometimes hundreds of thousands in overtime pay alone (Sedacca 2024, Tchekmedyian and Pringle 2025, Nelson 2015). At the same time, overtime is often allocated informally within these organizations. Is the concentration of overtime among a few individuals a sign that public resources are captured by influential insiders, or an efficient consequence of preference differences across workers? The answer has implications for the design of overtime systems, in particular whether reductions in overtime costs and inequality are possible without severely reducing worker surplus. Given the sheer magnitude of observed differences in overtime in publicized examples, and that markets rarely operate within firms, much less government organizations, we might expect influence to rule in efficiency's stead.

This paper demonstrates that an informal, influence-based institution inside a government organization can make relatively efficient allocations, and that the concentration of overtime in the hands of a few can reflect preference differences across workers. We study the Los Angeles Department of Transportation (LADOT), which assigns overtime equally initially using a rotating list system called "the wheel," but allows officers to trade informally. Despite initial equality of opportunity, a small number of traffic officers earned more than \$100,000 in overtime pay in a 1.5-year period. A government report found (Galperin 2015) and the *Los Angeles Times* reported (Nelson 2015) that this was the result of a "select few employees with insider relationships." We obtained and made public record fine-grained pay records which allow us to identify when officers worked in the same location on the same day and therefore recover the network of potential relationships within the organization. We show that an officer is several times more likely to work overtime when they are well-connected to the coworkers who were likely initially endowed with overtime, confirming that influence within the organization provides better access to overtime.

However, the inequality generated under informal trade turns out to be efficient, in that it largely reflects differences in preferences for overtime across workers rather than differences in insider access. The LADOT pairs essentially fair ex-ante assignment of overtime with an informal secondary market for overtime where shifts can be traded or sold without management intervention. These features, combined with the daily panel structure of the data, allow us to separate access from preferences. Decompositions reveal that removing differences in informal networks has a negligible impact on overtime inequality, while removing preference differences significantly reduces inequality. We further confirm this by counterfactually replacing informal trading with formal, centralized auctions where officers bid wages for shifts. Although uniform-wage auctions achieve the maximum possible allocative efficiency, informal trading achieves 93.8% and has essentially equal allocative efficiency as an uniform-markdown auction where officers bid markdowns from their union-negotiated wage. The counterfactual auctions also have no impact on or worsen inequality. The overtime wage savings from moving to these counterfactual auctions are modest, but the allocative efficiency lost from moving from informal trading to random assignment is large and equivalent to $4.1 million in lost earnings.

Our results rest on our ability to separate preferences from access to overtime. In many settings this is challenging, either because the systems used to assign work are unclear and complex, the employment contract and tasks vary across workers within the organization, or overtime assignments are dictated by managers and thus do not contain information about worker preferences. By studying Los Angeles traffic officers, we resolve all three challenges. The overtime assignment process, colloquially referred to as the wheel, is well understood by officers and can be accounted for using our data. There are over 400 active traffic officers at any given time, all of whom share the same occupation, job title, tasks, and pay scale, many of which are outlined in union-negotiated contracts. All are initially entitled to the same amount of overtime. Finally, and perhaps most importantly, they are allowed to buy, sell, or trade their overtime via an informal market that is unregulated by management. Officers desire overtime both because it is paid at 1.5 times their normal hourly wage, and because most overtime involves special events, which frequently feature professional athletes and celebrities.

The key technical challenge in our setting is accounting for the informal market. An officer who is observed working a large share of overtime may be doing so either because they enjoy working overtime or because they are well connected within the organization and have better access to overtime. We account for the informal market by tracking all the instances where two officers worked on the same day in the same location. For 90-day rolling windows prior to each work date, we sum up this measure for each pair of officers. We adjust for crowd-out by down weighting by the number of other officers present. This process generates a time-varying network of potential contact between all officers in the organization. We then identify the officers likely to have received overtime from the wheel by comparing the seniority of each officer to the approximate position of the wheel on each date. An officer's potential overtime supplier count on each date is then the sum of their potential contact with all other officers, weighted by each other officer's proximity to the wheel on that date.

We present our results in five parts. First, we establish a set of stylized facts which justify our modeling choices and reinforce the claims from government documents. Because officers are ordered on the wheel based on their seniority, and we observe hire dates, we are able to approximate the daily position of the wheel. Specifically, by taking the circular median of the seniority of officers that work on each date, we can observe the wheel turning in the data. The wheel turns often, as much as every day during the busy season, and when an officer is close to the median on a given date, they are more likely to work on that date. We show that despite the wheel's operation, the top 10% of officers work 36.3% of all overtime shifts. We finally show that officers well-connected to those close to the wheel position on a given date (potential overtime suppliers) are much more likely to work overtime on that date. Specifically, an officer-date with a potential supplier count in the bottom quartile has an average overtime probability of 9%, while an officer with a potential supplier count in the top quartile has an average overtime probability of 25.8%.

Second, we estimate officer preferences and access costs. We exploit the long panel structure of our data and use a logistic regression estimator with both date and officer fixed effects. We can include high-dimensional fixed effects in a nonlinear model because the LADOT employs over 400 non-probationary traffic officers, and we observe 1.5 years of daily overtime decisions, allowing us to use asymptotic incidental parameter bias corrections. We capture time-varying access costs by including an officer's angular distance from the wheel in terms of seniority on each date as well as an officer's potential supplier count. We show that our model captures changes in access caused by terminations and new hires. We estimate that access costs are $53 per shift, but these costs are reduced when an officer has more potential suppliers. We validate our model by using external data to show that our model estimates correctly capture the amenity value of different types of shifts. As an example, we show that the dates with 10 highest fixed effects include high-profile special events like the Oscars, MTV Movie Awards, Golden Globes, and private celebrity parties.

Third, we perform a Shapley-style decomposition of the share of overtime worked by the top 10% of officers, our preferred measure of inequality. We shut down three dimensions of heterogeneity in our decomposition: informal networks (insider influence), wage differences generated by being on different pay scale steps, and officer time-invariant overtime preferences. Removing informal network heterogeneity reduces the share of overtime worked by the top 10% of officers by 0.2 percentage points, which is small relative to baseline. In contrast, removing preference heterogeneity reduces the share of overtime worked by the top 10% of officers by 4.0 percentage points and removing wage heterogeneity increases inequality by 3.9 percentage points. Thus preferences, not insider access, are the main driver of observed inequality.

Fourth, we study a counterfactual uniform-wage shift auction, where officers bid wages for overtime, and a counterfactual uniform-markdown shift auction, where officers bid markdowns from the existing pay scale. While both shift auctions reduce wage costs for the LADOT by 4.79% and 3.66% respectively, these reductions mainly represent access cost savings of workers extracted by the LADOT via lower wages. Informal trading and uniform-markdown auctions generate similar levels of inequality, worker surplus, and allocative efficiency. Uniform-wage auctions allocate shifts to the officers that value them most, and thus achieve the maximum possible allocative efficiency. Even compared to this ideal mechanism, informal trading performs well, delivering 93.8% of the allocative efficiency and generating less overtime inequality. We show that moving from informal trade to random assignment reduces allocative efficiency by an amount equivalent to $4.1 million in earnings.

Finally, we ask why informal trade within the LADOT makes efficient allocations. We take the estimated overtime access costs and scale them up, scale them down, and change their correlation with officer preferences, recomputing the allocative efficiency of informal trade in each case. Informal trade makes efficient allocations because well-connected officers also tend to value overtime and because access costs are small. Intuitively, officers gain potential suppliers by working more in the past, and thus the network is encoded with the overtime preferences of officers, allowing it to make efficient allocations. The size of access costs and the encoding of the network are synergistic. If access costs were ten times larger, switching from the observed data to a case where potential supplier count and officer time-invariant preferences are perfectly negatively correlated decreases efficiency by 7.30 percentage points.

We consider our results in light of several potential concerns, including collusion by influential officers within the organization and incorrect estimation of access costs. We show our main result, that informal trade achieves 93.8% of the maximum possible allocative efficiency, is robust to moderate under and overestimation of access costs, as well as changes to the correlation between preferences and potential supplier count (network position). We also investigate the potential productivity implications for the organization. We do this by developing a proxy for traffic direction productivity that is based on collisions occurring within 400 meters of known overtime work locations.

Our paper contributes to the literature on worker assignment within organizations by focusing on informal decentralized mechanisms and their impact on worker surplus. Past work has studied a variety of settings, including the IMF (Barron and Vardy 2005), Teach for America (Jonathan M.V. Davis n.d.), the U.S. army (Jonathan MV Davis, Greenberg, and Jones n.d.), and a large multinational corporation (Minni 2024), but has largely focused on formal centralized mechanisms like deferred acceptance or direct assignment by managers. Ba et al. 2022, which studies the impact of switching police officers from a seniority-based assignment system to alternative mechanisms, explicitly accounts for officer preferences and is most similar to our paper in that regard.

Our paper speaks to a longstanding literature on the relationship between firms and markets (Coase 1993, Rosen 1988). A motivating question in this literature is why organizations exist within markets. We document a case where a market exists within a rigid and unionized government organization. An important aspect of our setting is that social networks alleviate frictions in this informal market for overtime, and in that respect our paper is similar to Bandiera, Barankay, and Rasul 2012, who study how performance pay interacts with social networks within the firm.

Several papers show that the preferences of workers need not align with the outcomes desired by the organization employing them. Examples include software development workers trading off productivity and job satisfaction (Cowgill et al. 2024) and teachers disliking work at schools at which they have a comparative advantage (Laverde et al. 2023). We consider the organizational goals of minimizing overtime inequality and maximizing worker surplus, and show that the informal trading system used by traffic officers within the LADOT achieves these goals fairly well relative to alternatives. Our finding that uniform-wage auctions potentially worsen productivity is more in line with past work, in that it demonstrates a tension between worker preferences and a potential organizational goal.

2 Institutional Details

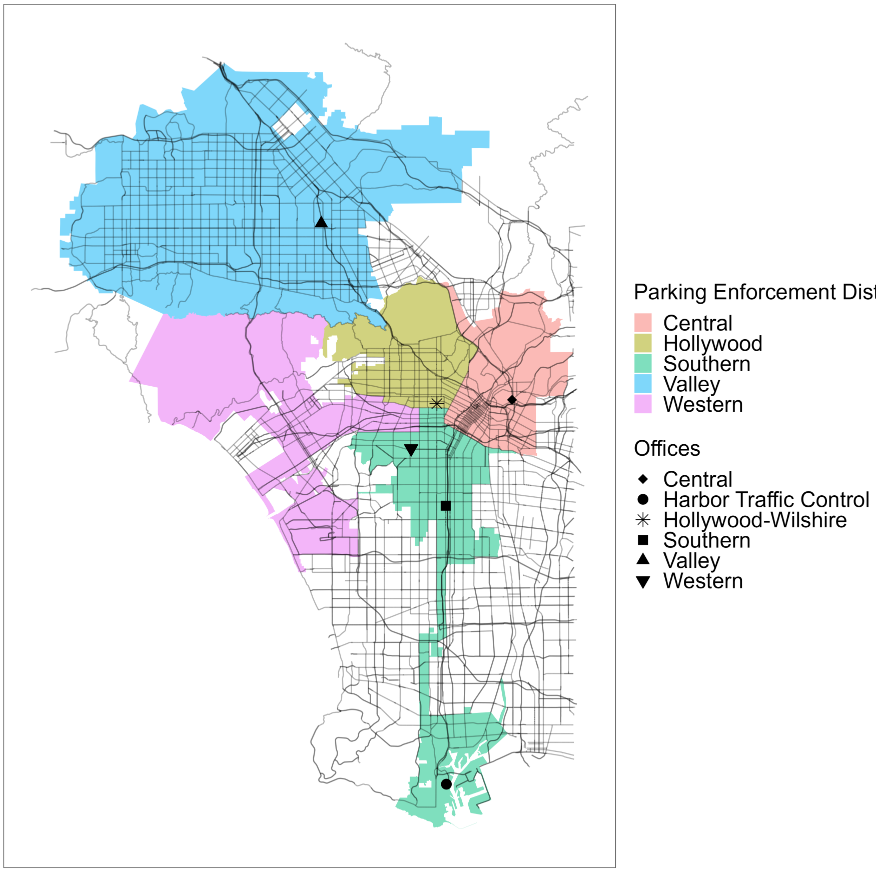
The population and setting studied in this analysis are traffic officers working in the Los Angeles Department of Transportation (LADOT). Los Angeles is divided into six geographic parking-enforcement districts. Each parking-enforcement district has an office. Offices and districts are depicted in Figure 1. Traffic officers operate over a large area: many parts of the Valley District are more than 40 miles from Harbor Traffic Control.

Traffic officers are allocated to divisions usually associated with the geographic districts. Regular work assignments are controlled at the division level, and special event work assignments, which we describe shortly, are disseminated to officers through their division but are largely coordinated centrally. Video footage posted by the LADOT shows that traffic officers do a roll call at their assigned office (LADOTOfficial 2018). For these reasons, we will refer to officers who work in the same division as "coworkers."

Traffic officers have two core duties: parking enforcement and traffic control.[1] Parking enforcement duties primarily consist of patrolling a designated beat to identify and cite

[1] City of Los Angeles Civil Service Commission 2009 describes the traffic officer role, and City of Los Angeles Personnel Department 2024 describes the core tasks.

Figure 1: Parking Enforcement Districts and Offices



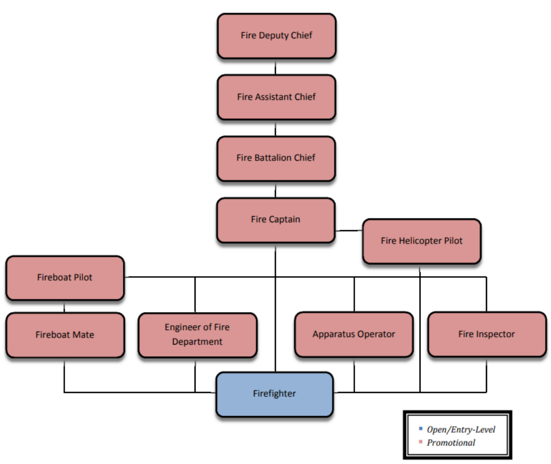
Note: Map created using Shapefiles from City of Los Angeles 2023 and office addresses obtained from Los Angeles Department of Transportation 2025.

vehicles and drivers in violation of Los Angeles and California codes, while traffic control duties consist of directing traffic at assigned locations to prevent gridlock, placing traffic control devices (e.g., barricades or flares), and managing roadways when traffic accidents occur. While some traffic work is routine (e.g., daily management of an intersection known to suffer from congestion), the vast majority is caused by permitted *special events*, which include the Los Angeles Marathon, Dodger games, the Oscars, parades, protests, and block parties. Los Angeles hosts several thousand permitted special events every year. Whenever a special event would impact traffic and parking in the city, traffic officers are dispatched. Thus, while these special events can create additional labor demand for traffic officers, these events involve many of the same tasks as routine traffic control.

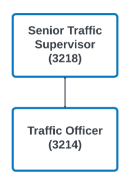
Around 80% of regularly scheduled traffic officer time is spent on parking enforcement, and most traffic officers are allocated exclusively to parking enforcement duties for their regularly scheduled working hours. Since the mid-2000s, the routine traffic control duties that comprise the other 20% of regularly scheduled time have also been performed by officers allocated exclusively to traffic control. Officers generally work alone when performing regularly scheduled parking-enforcement and traffic-control duties. Large special events are the primary scenario in which multiple officers would be working near each other.

We highlight that traffic officers are highly substitutable between shifts and work assignments. While the assigned beat and parking conditions can vary, the core task of parking enforcement is fundamentally identical between officers. While each special event is unique, traffic direction always consists of the same small set of tasks, several of which the LADOT documents in YouTube training videos (Parrish 2020). These tasks do not appear to create much opportunity for teamwork or complementarities between officers; a special event as large as the Oscars will require a large group of traffic officers, but there is not much scaling in the complexity of the work. Different traffic officers will have varying levels of productivity and skill but there is limited opportunity or need for specialization. This feature is highlighted in Figure 2, which shows the relative simplicity and lack of specialization in the career ladder for traffic officers relative to firefighters in Los Angeles.

Figure 2: Career Progressions for Firefighters and Traffic Officers



(a) Firefighter



(b) Traffic Officer

Note. Los Angeles provides a career ladder describing potential promotions and lateral movements for each employee classification (City of Los Angeles Personnel Department 2025). Panel A shows the ladder for firefighters, while Panel B shows the equivalent ladder for traffic officers.

Traffic officers are union employees covered by the Memorandum of Understanding 18 (MOU) between the City of Los Angeles and Service Employees International Union Local 721 (City of Los Angeles, Office of the City Administrative Officer 2015). According to the MOU, traffic officers are assigned fixed and regular workweeks and work schedules (e.g., a 5/8 or a 4/10 work schedule). The regular salary for traffic officers is standardized by the

MOU. During the period of our analysis, the MOU establishes the overall salary range as roughly $47,000 to $64,000. Exact salary is determined by tenure using a step structure. After completing the probationary period, a traffic officer will generally qualify for a step increase every twelve months, translating into a roughly 3% annual raise.

A consequence of the high degree of substitutability is that most traffic officers are eligible to complete overtime work, should the need arise. Based on a conversation we had with a traffic supervisor that we confirmed in our data,[2] the only officers excluded from special events overtime are those in their probationary period. Non-probationary Los Angeles traffic officers control their labor supply by working overtime shifts. Over 150,867 hours were billed to overtime pay codes in calendar year 2015. This overtime comes from two sources. First, routine overtime arises from excess demand for traffic control due to something like an emergency or a construction project (e.g., a burst pipe or a broken traffic light). Second, pursuant to the MOU, all special events work is paid out as overtime. Based on city reports, in fiscal year 2013-2014 (the year prior to our data), 80% of all overtime paid out to employees within the Department of Transportation Parking Enforcement and Traffic Control was due to special events.

The MOU prescribes a general policy for the assignment of overtime among traffic officers: "Management will attempt to assign overtime work as equitably as possible among all qualified employees in the same classification, in the same organizational unit and work location" (City of Los Angeles, Office of the City Administrative Officer 2015, 27). For this reason our paper focuses on the decision to work additional shifts rather than the decision to work additional hours.

How exactly overtime is assigned to individual officers is not spelled out in the MOU. However, a report by the City Controller's office (Galperin 2015) gives more detail about special-events overtime. Any event with sufficient advance notice is coordinated centrally by LADOT, and overtime is assigned using a mechanism officers call "spinning the wheel." Under the wheel system, officers first volunteer to be on an overtime list. The list is ordered by seniority. At the start of each month, the DOT "spins the wheel" by assigning special event overtime sequentially to officers in the order they appear on the list. The list is called a wheel because once the list is exhausted, it cycles back to the beginning again. Thus seniority serves as reference for where an officer is on the wheel, like the hours on a clock, but does not determine how much overtime an officer receives over a long horizon. For those events with less than six days' advance notice, an analogous version of the wheel is spun at

[2] Probationary officers appear in our data and in city documentation with the job title "Traffic Officer I," while non-probationary officers have the Title "Traffic Officer II." Across 43,805 person-days in our period of analysis, we find only one record of a Traffic Officer I working an overtime shift.

local area offices, using a list containing only the officers assigned to that office. The wheel system is implemented via a Microsoft Access program, created as part of a traffic officer's master's thesis.

The LADOT continues to spin the wheel month after month, as do the district offices with their wheel. Because the wheel spins continually, and given that thousands of special events occur each year in Los Angeles, the initial assignment of any particular officer to any particular special event is as good as random, and the cumulative amount of overtime assigned over any period longer than a few weeks will be similar across any officers who have volunteered. The city report states this explicitly:

> The wheel system ensures that overtime is initially assigned equally to all employees who desire to work overtime. Over a given time period, each employee in the Access database will basically be assigned the same number of special events.

In practice, the observed amount of overtime between officers varies wildly, a fact we document in Figure 5. This imbalance in overtime hours is largely the result of shift trading between officers. Once the wheel has been spun, special-event assignments are sent to area supervisors and posted on bulletin boards in staff areas. After seeing their assignment, an officer assigned an overtime shift may work it or find a substitute. Documentation of substitutions is not enforced by LADOT, but the aforementioned City Controller's report recounts that such trading is common. While only 192 officers signed up to volunteer in FY 2013-2014,[3] 471 officers worked overtime, suggesting that not only is trading pervasive, it even induces non-volunteers to work special events. During the period we consider, officers also had wide latitude to use any accumulated sick time or leave time to fulfill any scheduled non-overtime shift, including calling out of their scheduled shift to work a special-event overtime shift instead.[4] In sum, the combination of written policies and departmental norms within LADOT created a workplace in which most officers could work most overtime shifts, provided they could find a trading partner.

Crucially, trading overtime shifts requires a bilateral trade: an officer must give up an assigned shift and another officer must take on an unassigned shift. Special event overtime guarantees a higher pay rate and also the amenity value of working certain high-profile events and so many officers might be willing to trade into an overtime shift if it is not costly to do so. Among the thousands of special events in the period, some are particularly likely to

[3]This is the year prior to our analysis period, which spans part of FY 2014-2015 and all of FY 2015-2016.

[4]This possibility was in fact intended by the DOT and union to create more equitable access to overtime: unless officers were allowed to call out of a normal shift and work a contemporaneous special event, officers with work schedules that substantially overlap special events would rarely be able to work overtime.

involve exposure to celebrities. We list several notable examples in Table 1.

Table 1: Notable Special Events

Event Name	Date
57th Annual Grammy Awards	2/8/2015
Faith Evans' Grammy After Party	2/8/2015
The 87th Academy Awards (Oscars)	2/22/2015
Katy Perry Prismatic World Tour	3/26/2015
Ice Cube, MC Ren and Yella Concert (NWA Reunion)	6/29/2015
Taylor Swift Concert (1989 World Tour)	8/21/2015
Billionaire Dennis Tito's Holiday Party	12/11/2015

Shift trading between traffic officers may involve banking favors to be repaid in the future, the use of social status, and even side payments in cash.[5] We remain agnostic about the exact currencies used to facilitate any particular trade, but highlight that these trades all happen within a network. After the wheel is spun, special-event overtime assignments are publicly posted on bulletin boards in division offices. An officer seeking to trade for a desirable shift or trade away an undesirable shift needs to identify trading partners and convince them to trade. According to a supervisor, trades are facilitated both via word-of-mouth and via an informal online forum. In theory, any non-probationary officer may trade a shift; however, in practice an officer who cultivates a more extensive or dense network should have an advantage among their peers with regard to the flexibility and availability of overtime shifts. In city reports, Parking Enforcement and Traffic Control staff have raised concerns about officers who use their networks in exactly this way. Referring to these officers as "The Cartel," Galperin 2015 highlights that officers cultivate relationships to obtain high-value special event overtime shifts.

3 Data

We combine data from several sources. Our primary data set consists of payroll records for all Los Angeles traffic officers. The payroll data record daily work activity, including amount and type of wages paid and hours worked. The data come from a discontinued city project, and it was subsequently released as public record.[6]

[5] There is some disagreement between Galperin 2015 and a supervisor we spoke to within the LADOT about whether cash is used. Anecdotal reports from other government organizations suggest side payments do occur elsewhere.

[6] We provide the raw data in full at https://www.jkohlhepp.com/publication/selection-injury/.

We construct a daily panel data set tracking overtime and standard work between July 1, 2014 through June 30, 2016. We use the first six months (July 2014 through December 2014) to construct an initial history of officer work patterns. The rest of the data, which starts on January 1, 2015 and ends on June 30, 2016, is our analysis period. Summary statistics are provided at the officer-date level in the top panel of Table 2, and at the officer-level in the bottom panel. For officer-level statistics, we compute tenure and age to be as of January 1, 2015. We report summary statistics of number of regular shifts worked, number of overtime shifts worked, and number of dates active in the panel.

Table 2: Summary Statistics

Statistic (Officer-Date)	Mean	St. Dev.	Pctl(25)	Pctl(75)
Wage	29.988	2.356	30.540	30.540
Age	46.792	8.984	40.289	53.368
Tenure	15.039	8.140	9.139	19.313
Standard Work	0.673	0.469	0	1
Overtime	0.139	0.346	0	0
Expected Earnings	283.076	61.282	240.133	317.489

Officer-Dates: 274,908

Statistic (Officer)	Mean	St. Dev.	Pctl(25)	Pctl(75)
Wage	29.500	2.838	30.470	30.472
Age	45.843	9.198	39.254	52.761
Tenure	14.155	8.482	8.192	18.563
Days Active	513.847	95.414	547	547
Standard Work	345.817	65.884	368	372
Overtime	71.258	86.013	4	121

Officers: 535

Most officers are in their 40's with more than 8 years of traffic officer experience. Wages are quite similar across officers, reflecting a compressed, union-negotiated pay scale. We report expected earnings for each officer-date, which we compute as the average number of overtime hours among those who work overtime on each date multiplied by an officer's overtime rate. Most officer are active and observed for all 547 days of the analysis period. Most officers are observed working non-overtime (standard-work) hours on 370 days, with 50 percent of officers working between 368 and 372 non-overtime days. In contrast, the number of days each officer works overtime varies substantially, a fact that we document more extensively in the next section. Throughout the paper, we refer to an overtime shift as a day when an officer is observed working positive overtime hours. While 10 officers are observed working more than 300 overtime shifts, 54 officers never work overtime.

We augment the payroll records with information about daily weather patterns obtained from National Oceanic and Atmospheric Administration 2019. We obtain special event permit information from the dataset Los Angeles Department of Building and Safety 2025 and information on traffic collisions from Los Angeles Police Department 2025, both of which are publicly available on the Los Angeles City Data Portal.

4 Stylized Facts

Our first fact confirms that the wheel system can be observed operating in the data as described in the government report. The government report states that overtime is initially assigned based on seniority, and our conversation with a supervisor indicates that the wheel is always turning as new special events arise. To test these statements, we compute the seniority rank of officers on each date based on the set of active traffic officers. We then convert each officer's seniority to an angle on the unit circle, where the least senior officer on a date is 360 degrees and the most senior is $360/N$. We then compute the circular median on each date among only officers that work overtime, and obtain the following result.[7]

Fact 1. The circular median of seniority rank among officers that work overtime follows a cyclical pattern across time.

Put another way, the wheel is observable from aggregate overtime work patterns in the organization. We illustrate the result graphically for July and October 2015 in Figure 3. Similar patterns arise in other months and when the circular mean is used rather than the median. In October, the revolutions of the wheel can be clearly observed: the circular median of seniority begins close to 1 (the top of the list), rises above 400, then falls back down again, completing around five cycles in the month. The latter half of July looks similar to October, but the early part of July features a period where the circular median stays roughly stable for 1.5 weeks. This is because early July is one of the busiest times for special events (and therefore overtime), and as a result the wheel is making a full rotation almost every day.

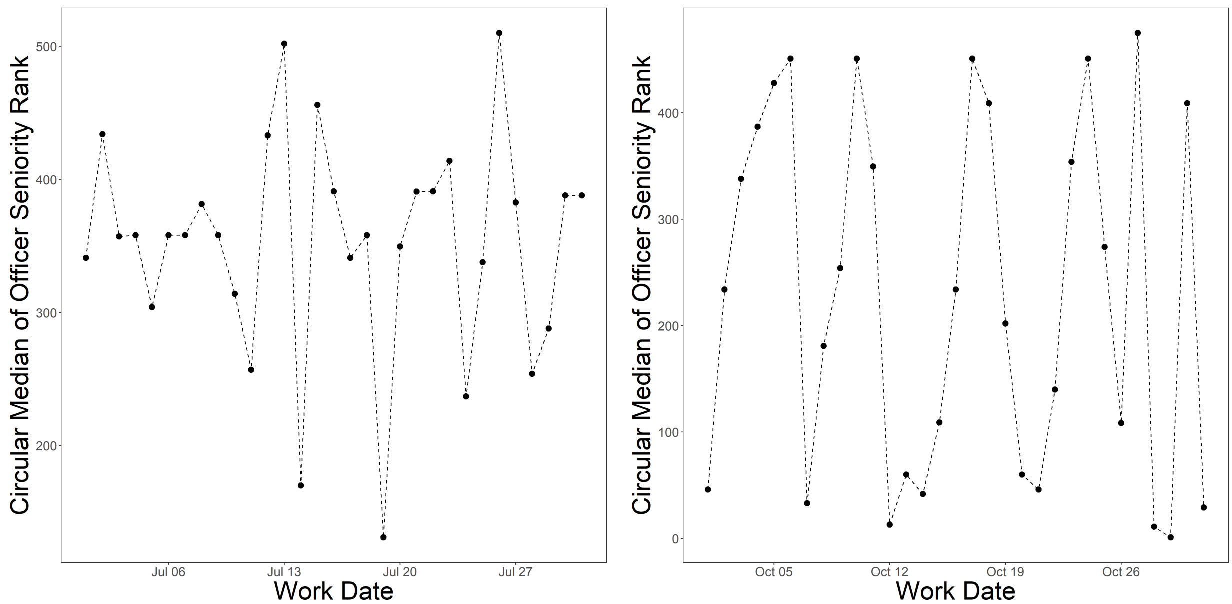
We stress that although we can approximate the position of the main organization-wide wheel on any given date, exact reconstruction of the wheel is not possible given the available data.[8] Nevertheless, we can show that an officer's distance from the approximate median of the wheel on any given date impacts the probability an officer works on a given date.

Fact 2. An officer with a seniority closer in angular distance from the approximate

[7]The circular median accounts for the fact that the most junior officer is close to the most senior officer.

[8]This is because multiple smaller wheels also operate, officers volunteer to be on the wheel, and around 20% of overtime does not come from the wheel.

Figure 3: The Overtime Wheel Turning



(a) July 2015 **(b)** October 2015

median of the wheel is more likely to work overtime.

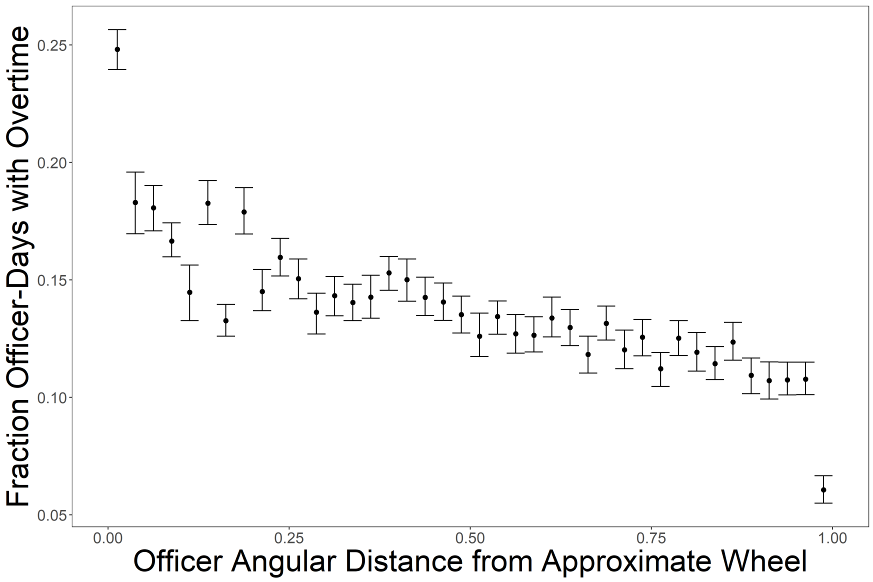
When computing the angular distance on date t of an officer i, we leave officer i out of the circular median of the seniority of officers who work overtime on date t. We plot the fact visually in Figure 4 by computing the overtime probability among officer-dates in 40 equally spaced bins based on angular distance from the leave-self-out median. The maximum distance of 1 corresponds to being on the other side (180 degrees) of the observed median of officers working that day, while a minimum distance of 0 corresponds to falling exactly on the observed median.

When an officer is almost exactly on our estimate of the approximate middle of the wheel, their probability of working overtime is 0.25. When an officer is on the opposite side of the wheel, their probability drops towards 0.05. The last two facts illustrate that the wheel plays a key role in granting access to overtime. However, the wheel is fair over a long horizon, so if it was the only way to access overtime, we would expect a relatively even distribution of overtime across officers.

Fact 3. A small number of officers work a disproportionate share of overtime.

We present Fact 3 visually in Figure 5, which plots a histogram of officers by the number of distinct dates they are observed working overtime. We confirm the finding in the government report: despite the wheel, overtime worked is distributed extremely unevenly, with a small number of officers working a large share of overtime. In the far-right tail we also confirm the existence of some officers who might be part of the "cartel" documented in the government

Figure 4: Distance from the Wheel and Overtime Access



Note. Standard errors are computed using 1,000 nonparametric bootstrap replications. The approximate wheel position is the leave-self-out-median of all officers that worked on each date.

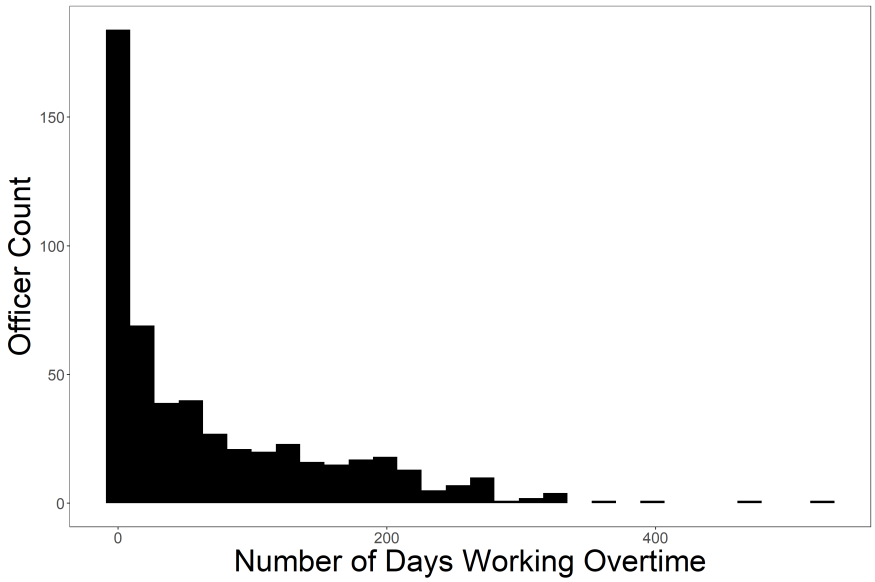
report. These officers are observed working overtime on 300 or more distinct dates in a 546-day period. In terms of inequality, the top 10% of officers work 36.3% of all overtime in the analysis period.

We provide several statistics to quantify the dispersion in overtime. An officer at the 25th percentile works 4 overtime shifts, while an officer at the 75th percentile works 121 shifts, which is 30.3 times more. If we limit only to officers observed working at least one overtime shift, dispersion is still large. An officer in this subsample at the 25th percentile works 12 overtime shifts, while an officer at the 75th percentile works 134 shifts, which is 11.2 times more.

A fixed number of special-event overtime shifts are distributed based on "wheels," one organization-wide and one for each division. An officer's initial position on the wheel is determined by seniority, but because the wheel is not reset and is always turning, overtime should initially be distributed evenly over a long time horizon. Yet the realized distribution of overtime is highly skewed, and the government report provides an explanation: "Traffic Officers may be able to receive more overtime if they have nurtured relationships and know how to network, treating overtime assignments as a privilege that can be traded." To assess this claim, we measure how well connected each officer could be within the organization, given work patterns in the time leading up to each overtime opportunity, and then we combine this information with the approximate position of the wheel.

We start by constructing the potential contact between two pairs of officers on date t,

Figure 5: Distribution of Overtime across Officers



which we denote $p_t(i, i')$. For officer pair (i, i') on date t, we check whether both officers worked at the same division. If they did not, we set $p_t(i, i') = 0$. If they did overlap, we compute the total number of officers who worked at that division, call it $N_{i,t}$ and set $p_t(i, i') = \frac{1}{N_{-i,t}}$. We measure the total potential contact between officer pair (i, i') prior to date t in the past $M = 90$ days as $c_t(i, i') := \sum_{\tau=t-1}^{t-M} p_\tau(i, i')$. We compute this measure for all pairs of officers and for all dates.[9]

The active officers on any date t are those hired on or before t and those terminated on or after t. For any fixed t, we can use the set of active officers and their pairwise measures $c_t(i, i')$ to construct a weighted undirected network G_t, which we call the network of potential contact. Two officers who never worked in the same division on the same day in the last 90 days are unconnected because $c_t(i, i') = 0$. Among those with a connection, the strength of that connection is proportional to the number of times they worked alongside each other weighted by the number of other officers present.

The measure $c_t(i, i')$ is meant to capture the fact that officers likely report to a shared district office to pick up their vehicles and gather information, but leave the office to perform their duties on different routes throughout the district. Further evidence for this view comes from promotional videos posted by the LADOT. These videos show officers gathered within the West Hollywood Parking Enforcement District Office, engaging in what appears to be a daily roll-call meeting. Our measure also captures crowd out: officers who overlap on a day where many other officers are working have less one-on-one contact. For example, parking

[9]We also compute the measure for different rolling window lengths M.

rules are relaxed on Sundays in Los Angeles, and the data reflect that fewer traffic officers work on Sundays. If two officers do happen to work on Sunday, we will calculate a high value of $c_t(i, i')$ because there are fewer other officers to crowd out their interaction.

We define a measure which summarizes an officer's centrality within the network of potential contact.

Definition 1 *Officer i's connectedness on date t is denoted by $c_{i,t}$, and is given by the sum of their potential contact with all other active officers up to but not including date t:*

$$c_{i,t} = \sum_{i' \neq i} c_{t-1}(i, i').$$

A one-unit increase in the measure is equivalent to one additional opportunity for a one-on-one interaction with another officer. A half-unit increase is equivalent to one additional opportunity to interact with another officer when a "third-wheel" officer is present. Connectedness measures how well-connected the officer could be given the set of officers they worked alongside prior to date t, incorporating both the breadth and depth of connections. Consider a connectedness of 60, a common value in the data. An officer could have this value if they overlapped with the same other officer in the same location for 60 of the last 90 days, and had no potential contact with anyone else. An officer could also have this value because they overlapped with two other officers in different locations for 30 days each.

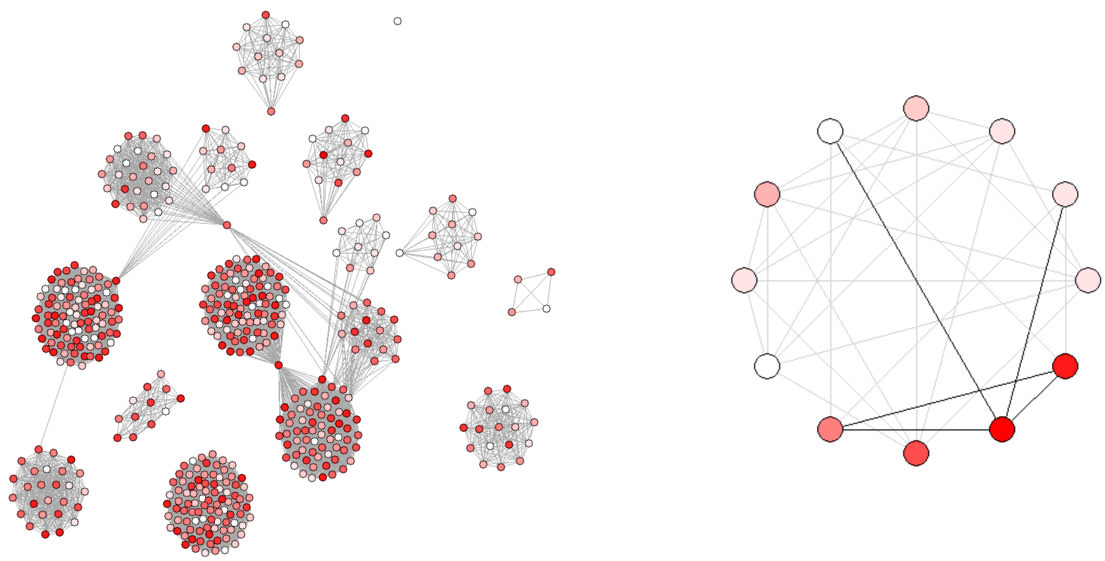
Fact 4. Connectedness varies both across officers and across time within officer.

Among all officer-days, the 25th percentile of connectedness is 59.7, while the 75 percentile is 65.8. Such a difference can be interpreted as 6 additional potential pairwise interactions. We illustrate the variation in the cross-section by depicting the network of potential contact on the first day of the analysis period in Figure 6. Each node is an officer, and each officer is colored based on the quantile of their connectedness on January 1, 2015. In Panel A we show the full network, where officers with any potential contact in the last three months are connected by a line. Large clusters typically reflect officers working in the same geographic division.

In Panel B we zoom in on a small disconnected part of the network to show that connection strength varies even within groups of officers who have all worked together. Schedule differences and variation in how often officers worked in the past drive differences in the strength of pairwise connections. All the officers in Panel B have worked together in the last 3 months, but a group within a group with especially strong connections (5 or more pairwise interactions).

In Figure 7, we illustrate within officer across time variation in officer 230's direct connections. The composition, number, and relative strength of officer 230's direct connections change throughout the period.

Figure 6: The Network of Potential Contact on January 1, 2015



(b) A Clique of Officers

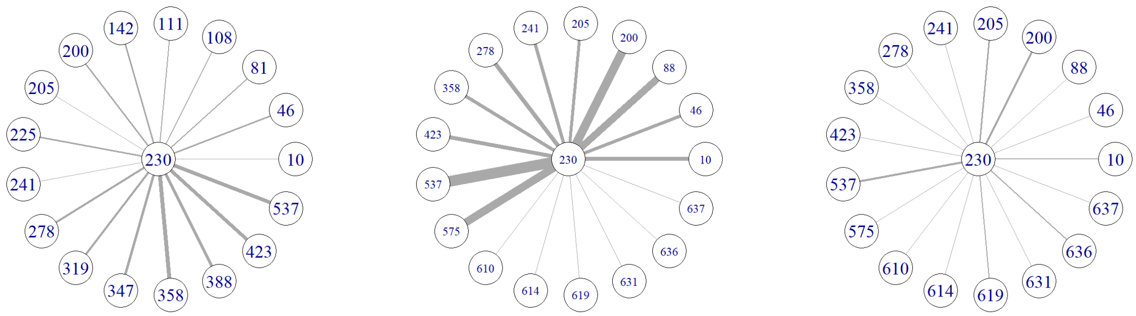
(a) All Officers

Note. Panel A features all employed traffic officer IIs on January 1, 2015. Two officers are plotted as connected if there is strictly positive potential contact in the last 3 months. Panel B focuses on a set of officers who are all connected to each other but disconnected from all others. Connections are plotted with a darkness based on the amount of potential contact. Officer node color is based on the connectedness, with red denoting high connectedness.

For an officer to obtain overtime on the secondary market, they must not just know people; they must also know the right people, more specifically the people endowed with overtime by the wheel. For officer i on date t, we compute the angular distance of officer i's seniority from the circular median seniority among all officers who worked on date t. We exclude officer i from the circular median if they happened to work that day. We call this quantity $A_{i,t}$, and we measure it in terms of half rotations, so that it is 1 when an officer is maximally distant from the approximate median of the wheel. We then use it to construct the following measure.

Definition 2 *Officer i's potential supplier count on date t is denoted by $z_{i,t}$, and is given by the sum of their potential contact with all other active officers up to but not including date t, weighted by the 1 minus the distance of each other officer from the leave-self-out circular*

Figure 7: Variation in Connectedness Across Time



(a) January 1, 2015 **(b)** July 1, 2015 **(c)** January 1, 2016

Note. The panels show the connections of Officer 230 at three different points in time, with the color of Officer 230's node related to their connectedness on each date.

median of the wheel on date t:

$$z_{i,t} = \sum_{i' \neq i} (1 - A_{i',t}) c_{t-1}(i, i').$$

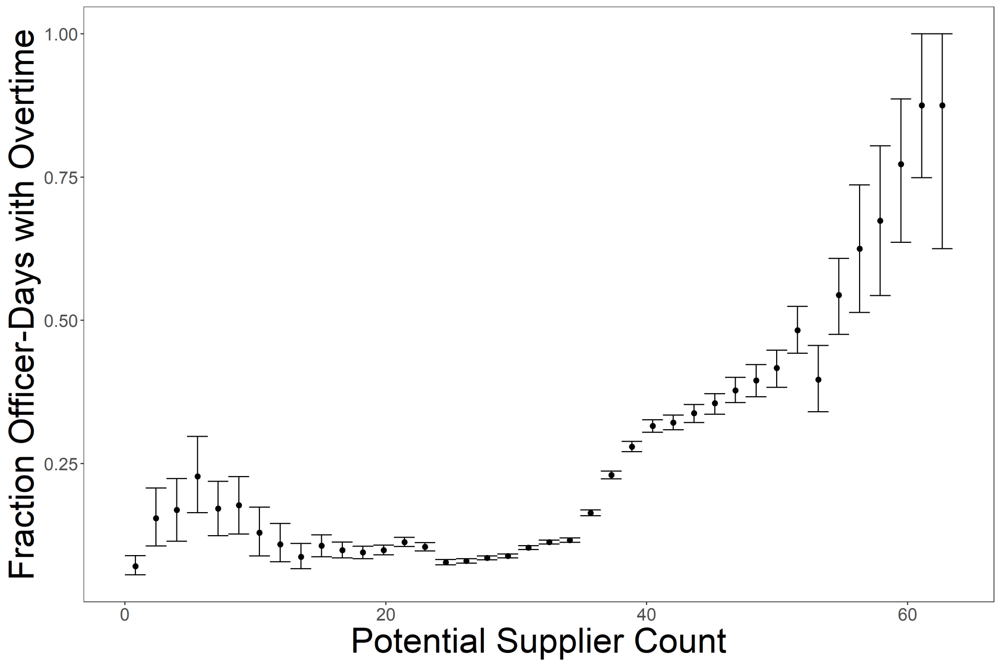
The measure is distinct from connectedness because it accounts for the fact that connections should matter for obtaining overtime only if they happen to be endowed with overtime. Thus a well-connected officer who has many connections far from the wheel position on a given date can have fewer potential overtime suppliers than a less well connected officer who has a handful of connections close to the wheel's position.

Fact 5. There is a strong positive association between potential supplier count and the probability of working overtime.

We capture this fact visually in Figure 8, where we compute the fraction of officer-days with overtime within 40 equally spaced bins based on potential supplier count. An officer-date in the bottom quartile of potential supplier count has an overtime probability of 0.090, while an officer-date in the top quartile has an overtime probability of 0.258. A potential supplier count near 60 is rare because it requires both high connectedness and alignment of the wheel, but when it happens the officer in question is observed working overtime the vast majority of the time. Appendix Figure 10 shows the strong positive association is also observed when we residualize both overtime and potential supplier count for officer fixed effects, date fixed effects, and several other controls.

Fact 5 is consistent with both the government report and conversations with a supervisor within the LADOT. The wheel determines initial allocations of overtime fairly. Afterwards, officers can bilaterally buy, sell or trade overtime without management intervention. This

Figure 8: Potential Supplier Count and Overtime Access



Note. Standard errors are computed using 1,000 nonparametric bootstrap replications.

exchange is done by word of mouth as well as via informal online forums. As the government report suggests, well-connected officers can obtain significantly more overtime because of better access. If officers all had the same preferences for overtime, we could conclude from Fact 5 that a greater number of suppliers reduce the cost of obtaining overtime, either by reducing transaction costs or by improving the buyer's bargaining position. In the next section we present a model we will use to disentangle preferences from access costs.

5 Empirical Strategy

We introduce a simple model where officers decide each day whether to work an overtime shift. The goal of the model is to separate preferences from access costs. We capture time-varying access costs due to direct assignment by the wheel using an officer's angular distance from the wheel position on each date. We capture time-varying access costs due to the secondary market using the potential supplier count.

5.1 Model

There are N officers indexed by i. An officer makes myopic daily decisions to work an overtime shift on dates $t = 1, 2, .., T$. Officer i's utility from working an overtime shift on date t is given by

$$u_{i,t} = \rho Wage_{i,t} + X'_{i,t}\beta_2 + \gamma_t + \alpha_i + \epsilon_{i,t}.$$

The monetary value of an overtime shift is captured by $Wage_{i,t}$, which is each officer's base rate times 1.5 (the overtime premium). Base rates mainly vary mechanically based on tenure and the union-negotiated pay scale. Officer-specific time-invariant utility from overtime is represented by α_i. Date-specific amenities of overtime are represented by γ_t. Utility is also allowed to depend on seniority rank within the organization on date t and whether the officer works standard hours that day, which are both included in $X_{i,t}$. We include seniority rank in utility in case there are effects of seniority not captured by our specification of access costs. We capture idiosyncratic taste for overtime with $\epsilon_{i,t}$, which we assume is i.i.d. standard logistic.[10] The parameter ρ converts non-wage amenities into the wage shift that generates the same utility. We define the earnings equivalent of utility x as x/ρ multiplied by 6.49, the average overtime shift length during the period.[11]

The cost of obtaining overtime is given by $A_{i,t}(\beta_2 + \beta_3 Z_{i,t})$, where recall $A_{i,t}$ is an officer's angular distance from our estimate of the median wheel position on date t and $Z_{i,t}$ is the potential supplier count of officer i on date t. Under this formulation, an officer exactly at the median faces no access costs because $A_{i,t} = 0$. Thus our specification embeds the assumption that on average, working an overtime shift when assigned directly by the wheel is costless. Given Fact 5, we expect more potential suppliers to reduce access costs, that is $\beta_3 > 0$. When an officer has no potential suppliers and is maximally distant from the wheel, $(Z_{i,t} = 0, A_{i,t} = 1)$ access costs are at their maximum and given by β_2. The reduction in access costs that comes from one additional potential contact being exactly at the median of the wheel is given by β_3.

We denote the binary overtime decision $W_{i,t}$. We normalize the utility of not working overtime to be 0. Officers make overtime decisions to maximize utility less costs, which implies their observed overtime decisions can be expressed as

$$W_{it} = \begin{cases} 1 \text{ if } \rho Wage_{i,t} + X'_{i,t}\beta_1 + \gamma_t + \alpha_i + \epsilon_{i,t} + A_{i,t}(\beta_2 + \beta_3 Z_{i,t}) \geq 0 \\ 0 \qquad \text{otherwise.} \end{cases} \tag{1}$$

The single-threshold model implied by this specification of utility and costs reveals the key empirical challenge. An officer who does not work many overtime shifts may be doing so

[10]This is equivalent to assuming a type-1 extreme value structural error term in the utility from overtime and no overtime.

[11]We use earnings equivalents primarily to compare wage costs and worker surplus.

either because they prefer not to work overtime or because access is costly given their wheel position and their potential suppliers within the organization. Disentangling preferences from access requires accounting for the officer's position in the organization on each date. If this is not done, our estimates of the main source of preference heterogeneity, $\hat{\alpha}_i$, will be biased.

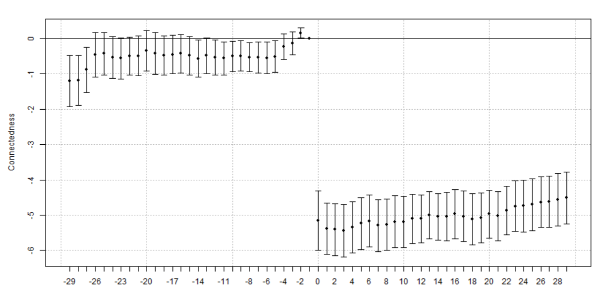
Our preferred specification does not include dynamic terms, like lagged overtime, which would allow for diminishing marginal utility from overtime. In Appendix Section 12, we estimate models with lags of both overtime and normal work and find positive coefficients on all lags of overtime, suggesting that there is no evidence of diminishing marginal utility from overtime. Because the wheel cycles frequently, the coefficients from such a lagged specification should be interpreted with caution.

5.2 Capturing Time-Varying Access

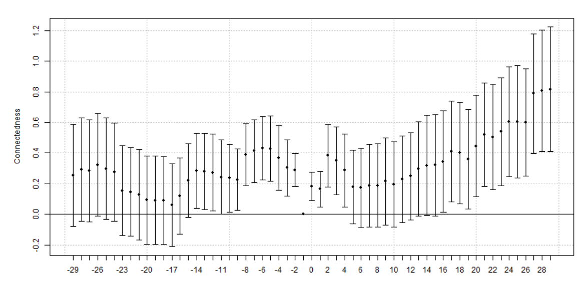
In this section, we show how personnel changes of surrounding officers translate into the connectedness of a focal officer. Specifically, we show that an officer's potential supplier count falls when a coworker terminates/retires and rises when an officer is hired in their division. In the process, we demonstrate how our approach accounts for time-varying access when estimating preferences for overtime. We use connectedness rather than potential supplier count because connectedness avoids the high-frequency noise induced by the wheel.

We consider the impact of a termination or retirement on all officers who worked in the same division on the same day as the terminated officer at least one of the 90 days prior to the termination. Second, we consider the impact of a new hire on all officers working in the same division on the same day as the focal officer. We run two-way fixed effects regressions that allow for dynamic effects and plot the coefficients in Figure 9, with the understanding that these are associations rather than causal effects.

Figure 9: Time-Varying Access



(a) Connected Termination/Retirement



(b) Connected New Hire

The termination of a connected officer leads to an immediate and large reduction in connectedness. It takes several months for connectedness to recover. The officers who happen to work in the same location on a new hire's first day experience a small increase in connectedness in the days immediately before and after, and then a month later a large increase likely due to sustained exposure to the new hire via schedule overlap. Because the wheel assigns overtime opportunities to all active traffic officers, coworker terminations make it more difficult for officers to access overtime, while new hires make it easier for officers to access overtime.

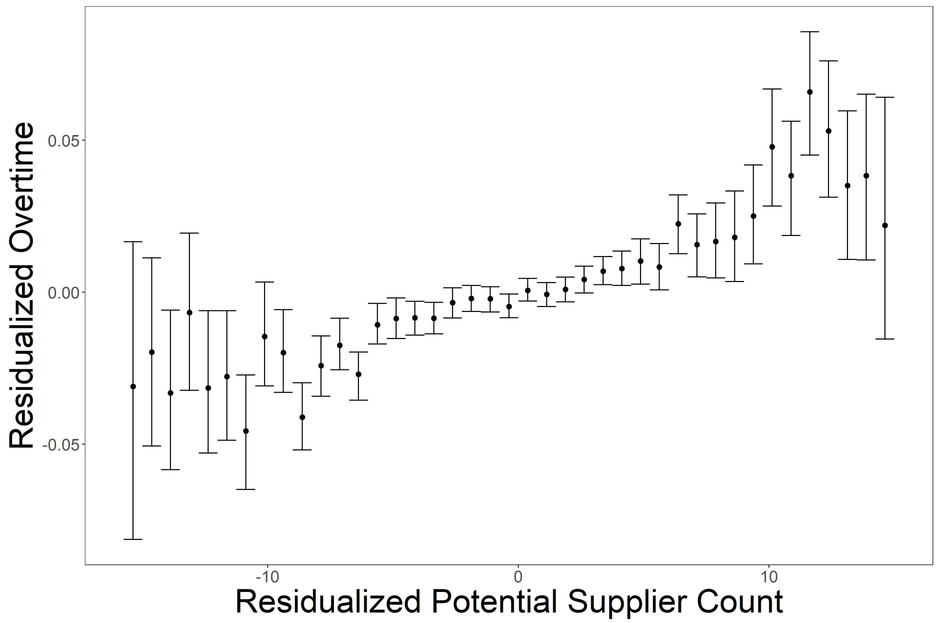
It is important to note that connectedness is related to but not the same as potential supplier count. If all of an officer's connections were endowed with overtime every day, the two measures would be the same. But since they are not, potential supplier count down weights connected officers whose seniority is far from the wheel's position on a date and up weights connected officers whose seniority is close to the wheel's position on a date.

5.3 Testing Identifying Assumptions

Identifying officer preferences relies on two main assumptions. First, angular distance from the wheel and potential supplier count must capture the cost of obtaining overtime. The government report states that networking and connections are drivers of overtime dispersion. Because we do not observe trades, we cannot test this directly. But we can test it indirectly: if potential supplier count captures the cost of obtaining overtime, it should be relevant to the decision to work overtime even conditional on all control variables, most importantly officer fixed effects. Stated more formally, $Cov(W_{i,t}, Z_{i,t}|i, X_{i,t}, Wage_{i,t}, A_{i,t}) >> 0$. Second, within-officer across time variation in potential supplier count cannot be correlated with within-officer across time variation in officer preferences for overtime. Stated formally: $Cov(Z_{i,t}, \epsilon_{i,t}|i) = 0$.

We provide evidence that potential supplier count is relevant to the overtime decision conditional on all other controls in Figure 10.

Figure 10: Binned Scatter Plot of Residualized Potential Supplier Count and Residualized Overtime



Note. Standard errors are computed using the nonparametric bootstrap and 1,000 replications. Both variables are residualized for date and officer fixed effects as well as the other time-varying controls. Observations with residualized supplier count in the top 1% and bottom 1% are excluded for visual clarity.

Comparing Figure 10 to the unconditional binned scatter plot in Figure 8, we see that residualizing removes some of the association between potential supplier count and overtime. Most of this correlated variation is cross-sectional and is removed by the officer fixed effects, reflecting the fact that officers who enjoy working overtime are on average better connected within the LADOT. Still, residualized potential supplier count remains strongly positively correlated with working overtime: across its support, average overtime probability increases by around 10 percentage points.

We provide two pieces of evidence that $Cov(Z_{i,t}, \epsilon_{i,t}|i) = 0$. We first note that this is a conditional requirement: the individual fixed effects allow officers with a strong time-invariant preference for overtime to have more potential suppliers on average. Consistent estimation of Equation 1 requires only that within-officer across time variation in potential supplier count is not correlated with within-officer across time variation in preferences for overtime. The assumption is also crucial for our interpretation of β_2 as the marginal reduction in the cost of obtaining overtime as an officer becomes more connected to another officer who is endowed with overtime. If $Cov(Z_{i,t}, \epsilon_{i,t}|i) > 0$, β_2 will implicitly include officer preferences and we will underestimate access costs. When we set β_2 to be 0 in our counterfactual exercises, we would then be accidentally modifying officer preferences rather than holding preferences fixed and modifying only the assignment system.

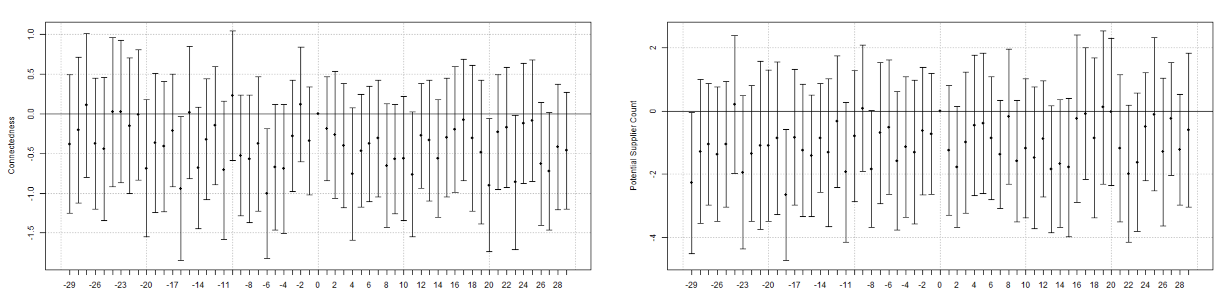
We first proxy for time-varying overtime preferences using family medical leave and bereavement pay codes. The argument underlying this test is as follows. The death of a family member, the birth of a child, or the need to take care of a family member all represent negative time-varying shocks to the value of working overtime ($\epsilon_{i,t}$). If such shocks are associated with reductions in connectedness, this is direct evidence that our assumption $Cov(Z_{i,t}, \epsilon_{i,t}|i) = 0$ is violated.

We implement this test by running two-way fixed-effect regressions of connectedness on a treatment indicator $D_{i,t}$ where an officer is treated when when they are first observed with the relevant pay code, which is defined as one with the text "BEREAVEMENT" for the bereavement "treatment" and "FML" or "FAMILY" for the family medical leave "treatment." The outcome is potential suppliers without any lag. We observe 57 officers "treated" with bereavement at some point in the sample and 398 "treated" by family medical leave at some point in the sample. We run non-dynamic two-way fixed-effect regressions of the form

$$Z_{i,t} = a_i + g_t + BD_{i,t} + e_{i,t}.$$

We find no evidence that our assumption is violated. For family medical leave we estimate $\hat{B} = 0.57$ (s.e. of 0.310). This effect is the opposite sign we would expect, and it is not statistically significant at the 0.05 level. For bereavement we estimate $\hat{B} = 0.46$ (s.e. of 0.852). This is again positive and not statistically significant at the 0.05 level. Interestingly, while none of the officers in our sample work normal hours on a day they take bereavement, two work overtime on days they take bereavement. We also ask whether there are dynamic effects. We do this by augmenting the two-way fixed-effect regressions with relative time indicators to capture the potentially changing impact of bereavement or family medical leave over time. We make coefficients relative to the day the pay code is observed. The results are depicted graphically in Figure 11. We find no evidence of dynamic effects.

Figure 11: Potential Supplier Count and Time-Varying Preferences for Overtime



(a) Family Medical Leave **(b)** Bereavement

We second check to see how much of the correlation between connectedness and overtime is due to connections formed very recently. We focus on connectedness because potential supplier count varies dramatically day by day due to the mechanical turning of the wheel. The argument underlying this test is as follows. As an officer approaches date t, more and more of the time-varying component of overtime utility ($\epsilon_{i,t}$) becomes known. For example, an officer with children does not know whether he/she will be well-rested prior to the shift until the morning of the shift. As another example, although the wheel turns mechanically, the exact number of officers needed for each event and unplanned events like protests imply that who will be assigned which special event is stochastic but becomes progressively more deterministic as date t approaches.

Thus, at any date τ prior to date t, the portion of $\epsilon_{i,t}$ that is unknown is conditionally independent of connections formed prior to date τ because an officer cannot condition his/her behavior on what is not yet known. The portion of $\epsilon_{i,t}$ that is known may be correlated with connectedness if the officer can manipulate the scheduling process to come into contact with more coworkers and have a better chance at working (or not working) overtime on date t. As a result, if more identifying variation in connectedness comes from the distant past, $Cov(Z_{i,t}, \epsilon_{i,t}|i) = 0$ becomes a more credible assumption.

We compute the proportion of the identifying variation that comes from the recent past by reconstructing connectedness with different amounts of lag. In our baseline specification connectedness is constructed using the 90 days prior to each date t, up to and including $t-1$. We construct new measures of connectedness that include the 90 days prior to a lagged date $t-1-l$, where we set $l = 7, 14, 21$. As connectedness is lagged longer, more of $\epsilon_{i,t}$ becomes unknown to the officer. At the same time, connectedness should become less predictive of overtime, as contact with others farther in the past is less important for obtaining overtime now. If the coefficient on connectedness becomes statistically or economically small even for short lags, we should be concerned that a large share of identifying variation is contaminated by omitted variable bias. We regress the overtime indicator on lagged connectedness and the controls in our main specification in Table 3. We standardized connectedness by dividing by its sample standard deviation, so that the coefficient can be interpreted as the expected increase in overtime probability for a one standard deviation increase in connectedness.

The effect of connectedness lagged by one week, two weeks, three weeks and four weeks is smaller than the original measure by 22.2%, 38.4%, 47.3%, and 58.6% respectively. As we anticipated, lagging connectedness reduces its predictive power. However, the coefficient remains statistically significant at the 0.05 level, and much of the identifying variation remains even when we exclude all potential contact from the last month. Further, the coefficients remain economically significant: even when connectedness is lagged by a month, a one stan-

Table 3: The Role of Lagged Connectedness on the Extensive Margin of Overtime

Dependent Variable:			Overtime		
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
Std. Connectedness	0.0208***				
	(0.0046)				
Std. Connectedness (Lag 7)		0.0163***			
		(0.0043)			
Std. Connectedness (Lag 14)			0.0129**		
			(0.0042)		
Std. Connectedness (Lag 21)				0.0112**	
				(0.0041)	
Std. Connectedness (Lag 28)					0.0088*
					(0.0040)
Distance from Wheel Median	-0.0846***	-0.0847***	-0.0855***	-0.0854***	-0.0864***
	(0.0056)	(0.0057)	(0.0057)	(0.0057)	(0.0058)
Normal Work	0.0234***	0.0225***	0.0227***	0.0230***	0.0232***
	(0.0043)	(0.0044)	(0.0044)	(0.0044)	(0.0044)
Seniority Rank	-0.0010	-0.0012	-0.0014	-0.0015	-0.0016
	(0.0015)	(0.0016)	(0.0016)	(0.0016)	(0.0016)
ot_rate	0.0120***	0.0119***	0.0119***	0.0117***	0.0117***
	(0.0023)	(0.0023)	(0.0023)	(0.0024)	(0.0024)
Fixed-effects					
Officer	Yes	Yes	Yes	Yes	Yes
Date	Yes	Yes	Yes	Yes	Yes
Fit statistics					
R^2	0.23550	0.23617	0.23595	0.23625	0.23655

Clustered (Officer) standard-errors in parentheses
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05*

Note: Standard errors are clustered at the officer level.

dard deviation increase in connectedness is expected to increase the probability of working overtime by 0.9 percentage points. Relative to a baseline probability of 16.1 percentage points, this is large. This finding confirms the valuations are not completely driven by variation in connectedness from the recent past, but are rather driven by the accumulation of interactions over the entire 90-day period.

Another way to interpret these results is that planned special events[12] are assigned to officers by the wheel at the beginning of the month. Lagging connectedness by one month therefore implies that we are using only connections formed prior to the posting of assignments. Even if an officer could manipulate their work schedule, it would be extremely difficult to know whom to try to work alongside to get a specific shift on a specific date so far in advance. Our results imply that such hard-to-manipulate connections account for 41.4% of

[12]The government report states in the year prior to our data these represented the vast majority of special events.

the variation in access.

5.4 Estimation

For estimation, we exclude 87 officers who work little to no overtime.[13] We compute an officer's base pay rate on each date as the highest rate observed among work-related pay codes that is less than $34. For dates where an officer does not work, we use the base rate from the most recent work date. We can include both officer and date fixed effects in a nonlinear model because we have a long panel. We employ the analytical bias corrections from Fernández-Val and Weidner 2016 as implemented by Stammann 2017.

We present coefficients on the time-varying variables in Table 4, along with average partial effects. We also present the estimates from a probit model, to illustrate that the average partial effects implied by our estimates are similar under either parametric assumption. The coefficient on the distance from the wheel median is negative, while the coefficient on potential supplier count is positive, consistent with the existence of access costs generated by the formal wheel system that are mitigated by an informal connections. The coefficient on distance from the wheel median is statistically significant at the 0.05 level and economically significant: it implies that the cost of accessing overtime when an officer is maximally distant from the wheel median (low direct access) and has no potential suppliers (low indirect access) is equivalent to $53 in earnings. The coefficient on potential supplier count is also statistically and economically significant: each additional potential supplier reduces access costs by an amount equivalent to $0.90 in earnings. The average partial effect on seniority rank is 0. This is reassuring, because it suggests the way we model the wheel and informal connections captures the impacts of seniority rank on overtime access.

In Figure 12, we also plot the distributions of officer fixed effects and date fixed effects, denominated in equivalent earnings. The estimates imply that officers value overtime shifts quite differently: in earnings equivalent terms, an officer with a fixed effect at the 75th percentile values an overtime shift $94 more than an officer at the 25th percentile. Heterogeneity in valuations across dates is smaller but still meaningful. If we fix an officer, the date fixed effects imply that a date at the 75th percentile is valued $20 more in earnings equivalent terms than a date at the 25th percentile.

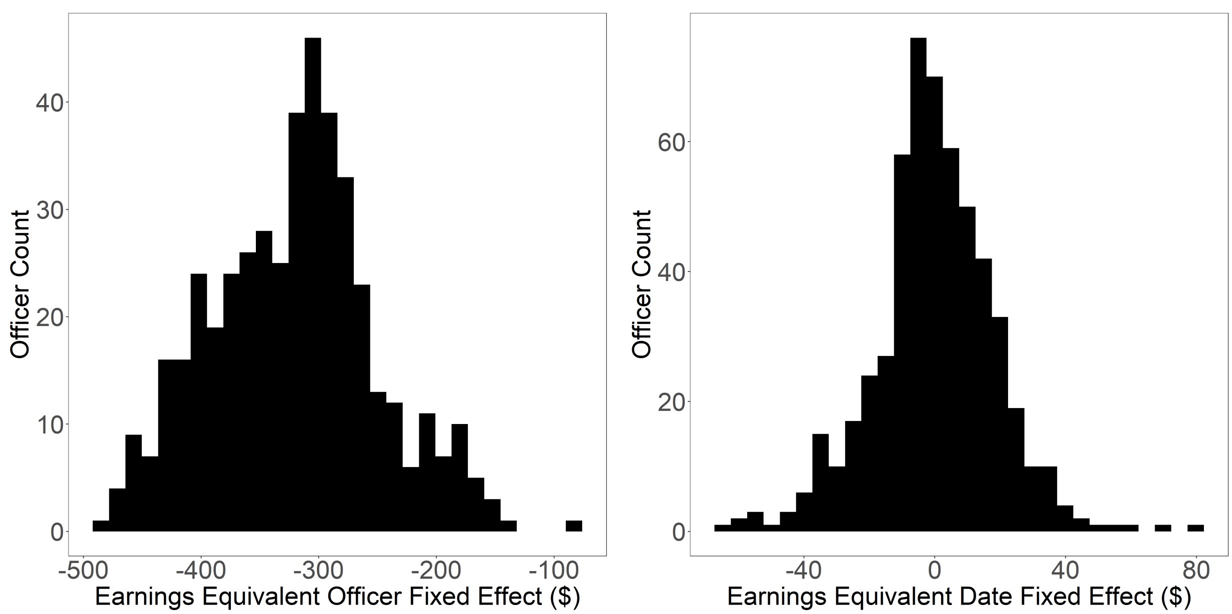
[13] Of these, 54 never work overtime. 33 worked 6 or fewer overtime instances ,and as a result their safety skill, discussed in Section 8.2, cannot be estimated.

Table 4: Model Estimates

Variable	Estimate (Logit)	APE (Logit)	Estimate (Probit)	APE (Probit)
Distance from Wheel	-1.776	-0.179	-0.987	-0.176
	(0.138)	(0.007)	(0.076)	(0.007)
Normal Work	0.220	0.022	0.117	0.021
	(0.042)	(0.002)	(0.023)	(0.002)
Overtime Wage	0.216	0.022	0.125	0.022
	(0.037)	(0.001)	(0.020)	(0.001)
Seniority Rank	-0.005	-0.000	-0.002	-0.000
	(0.014)	(0.000)	(0.008)	(0.000)
Supplier Count x Distance from Wheel	0.030	0.003	0.017	0.003
	(0.004)	(0.000)	(0.002)	(0.000)

Note: Standard errors are clustered at the officer level. The main specification assumes logistic unobservables and is displayed in the first column.

Figure 12: Estimated Fixed-Effect Distributions



(a) Officer Fixed Effects **(b)** Date Fixed Effects

Average potential supplier count is positively correlated with preference for overtime, but not perfectly so. We illustrate this in Table 5, which displays the fixed effects (preference estimates) alongside average connectedness and potential supplier count among officers who are likely part of the "cartel." We define likely members of the cartel as the officers who work more than 300 overtime shifts in the 547 analysis period.

As the government report suggests, the officers who work the most overtime are by and large the most well-connected in the organization. Being well connected usually but not always implies better access to overtime in terms of more potential suppliers. Discrepancies between the measures reflect the fact that access depends not just on how many people

Table 5: The Cartel

	OT Shifts		Avg. Connectedness		Avg. Suppliers		Fixed Effect	
Officer ID	Value	Rank	Value	Rank	Value	Rank	Value	Rank
537	524	1	89.3	1	45.12	1	$-82.79	1
432	473	2	84.06	2	34.69	73	$-200.03	27
200	390	3	78.66	7	40.23	4	$-146.18	3
373	368	4	76.53	9	40.83	3	$-240.7	56
124	330	5	78.73	6	39.6	9	$-270.68	93
308	325	6	82.02	3	43.76	2	$-245.53	60
264	317	7	80.53	5	40.05	6	$-253.43	69
471	317	7	80.59	4	39.6	10	$-230.28	45
394	316	8	69.87	48	37.18	27	$-250.89	65
44	304	9	74.15	20	33.91	96	$-269.25	90

Note: Overtime valuations, connectedness, and number of overtime shifts worked among likely members of the cartel.

an officer knows but the relative distribution of these people across the wheel of seniority. We finally observe that, with the exception of officer 200 and officer 537, the other 8 likely members of the cartel do not value overtime that much relative to their peers. For example, officer 308 is the third most connected and has the second most potential suppliers and as a consequence works the 6th most overtime shifts. However, officer 308 has a lower valuation of overtime than 59 other officers. Such patterns hint at the gain from alternative assignment mechanisms like shift auctions. By assigning work based on who values it most (or, who dislikes it the least) rather than who has the best access, the organization may increase aggregate officer surplus.

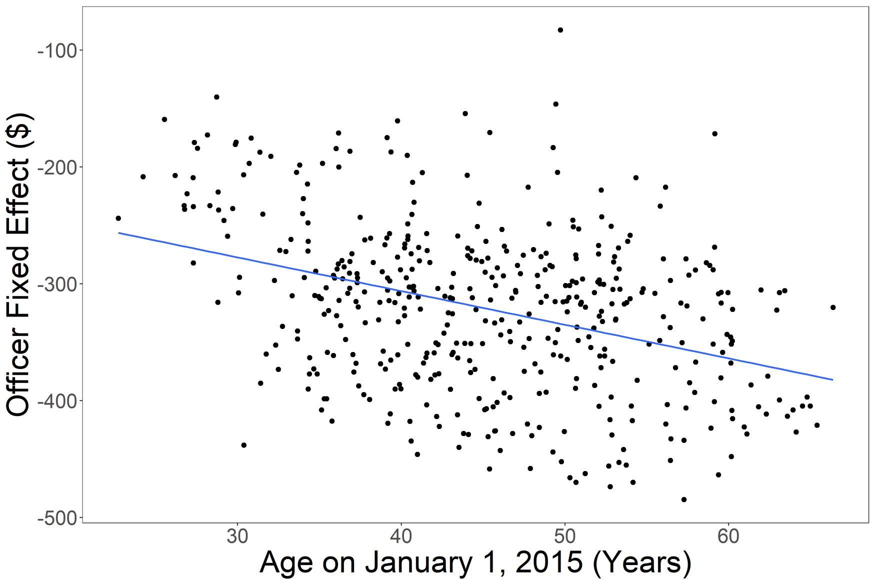
In contrast to the cartel, some officers are estimated to a strong preference for overtime because they worked a decent amount of overtime despite being poorly connected. For example, there is an officer who has fewer potential suppliers than 419 other officers but who is observed working 131 overtime shifts. As a consequence, this officer is estimated to have the second-highest overtime valuation. If informal trading via the internal network is replaced by a centralized system, this officer would likely work significantly more overtime.

5.5 Validation

We validate our estimates using two pieces of data that were not incorporated in estimation. We show that officer fixed effects, which we interpret as person-specific overtime valuations, are strongly negatively correlated with officer age. We then show that date fixed effects, which we interpret as the average amenity value of working the special events on date t, are highest on dates with a large celebrity presence.

We begin with the officer fixed effects. We plot all officer fixed effects against officer age on January 1, 2015 in Figure 13. There is a negative correlation between the fixed effects and officer age of -0.37. On average, an officer a year older values the same overtime shift \$2.88 less, consistent with a labor supply elasticity that is decreasing in age.

Figure 13: The Association Between Officer Fixed Effects and Age



We next consider our estimates of the date fixed effects $\hat{\gamma}_t$, converted to be in terms of earnings equivalents. If we are correctly capturing officer valuations for shifts with our empirical specification, the date fixed effects should reflect the average amenity value of working overtime on a specific date. We residualize the fixed effects so that they are not mechanically higher on dates when more officers are needed.[14] Thus, the fixed effects can be interpreted as indicating the amenity value of a shift relative to other dates with the same number of officers working overtime.

We then take the 10 dates with the highest adjusted fixed effects, and we read the special event permits listed for each date. We record the most notable event among the list of special events. If our model is capturing officer valuations, the top 10 dates should be those with high amenity value. Table 6 shows this is indeed the case.

Of the several hundred dates in the data, the dates with the highest fixed effects had particularly notable special events. Popular press articles indicate that many of these specific events involved large numbers of celebrities or professional athletes. Because we did not use the special-event permit information during estimation, this gives us confidence that our estimates are capturing underlying officer preferences. We emphasize that it is difficult to identify all notable special events, as descriptions are sometimes vague and not all special

[14]We regress the fixed effects on fixed effects for the number of officers working overtime that day and take the residual.

Table 6: Highest Adjusted Fixed Effects and Notable Special Events

Date	Notable Event	Fixed Effect Earnings Equivalent	Total Overtime
February 22, 2015	2015 Academy Awards (Oscars)	$9.59	84
April 11, 2015	2015 MTV Movie Awards	$9.22	101
April 26, 2015	2015 Daytime Emmy Awards	$8.53	77
January 03, 2015	New Year's Race	$8.41	75
April 19, 2015	LACMA 50th w/ Will Ferrell and Jim Carrey	$8.00	95
January 01, 2015	New Year's Eve Parties	$7.78	65
January 11, 2015	Amy Poehler's Golden Globes After Party	$7.42	55
February 21, 2015	Oscar's Night Before Party w/ George Clooney and Reese Witherspoon	$7.31	105
May 25, 2015		$6.74	105
January 21, 2015	Guild of Music Supervisors Awards	$6.73	63

events are documented by the popular press. For example, many of the special events listed on January 1, 2015 are New Year's Eve parties with ambiguous descriptions. But parties large enough to require street closures and special-event permits likely also involved celebrities.

We provide additional evidence by examining average adjusted fixed effects for different days of the week and on days when it did or did not rain. Recall that officers have a normal work schedule that they must accommodate when taking on special events. The wheel is not designed around it, and if the special event conflicts with an officer's normal work, they must take time off using sick or vacation banks to attend. As a result, if our fixed effects reflect average valuations, they should be lower on week days when a larger share of officers need to work their normal shift. Rain is not common in Los Angeles, it can be predicted beforehand, and traffic officers perform most of their duties outdoors. As a result, if the the date fixed effects reflect amenity value, they should be lower on dates with rain. We find in Table 7 that both patterns hold. The average fixed effect is negative for all week days and positive on weekends. Although there are not many days with rain, those dates have lower date fixed effects.

Table 7: Average Adjusted Fixed Effect by Day of Week and Rain

Type of Day	Number of Dates	Avg. Fixed Effect	Avg. Overtime Shifts
No Rain	502	$0.01	70.27
Rain	45	$-0.07	63.29
Thursday	79	$-0.51	69.75
Friday	78	$-0.41	75.42
Saturday	78	$1.80	71.78
Sunday	78	$1.99	67.05
Monday	78	$-0.57	68.29
Tuesday	78	$-1.13	67.49
Wednesday	78	$-1.16	68.08

6 Decomposing Overtime Inequality

We use our estimates to decompose the sources of overtime inequality, and show that preference heterogeneity rather than differences in informal networks are the main driver of observed inequality. Wage differences across officers, due to the union-negotiated tenure-based pay scale, tend to reduce overtime inequality.

If we examine our specification for the utility from working an overtime shift, three channels drive differences in the amount of overtime officers work:

$$\underbrace{\rho Wage_{i,t}}_{\text{Pay Scale}} + A_{i,t}(\beta_2 + \underbrace{\beta_3 Z_{i,t}}_{\text{Informal Network}}) + X'_{i,t}\beta_2 + \gamma_t + \underbrace{\alpha_i}_{\text{Non-wage Preferences}} + \epsilon_{i,t}$$

1. **Informal Network.** Well-connected officers will have more potential suppliers and can therefore access more overtime via informal trading.

2. **Pay Scale.** Officers at a higher pay scale will have a higher base rate, which will increase the pay they receive from an overtime shift.

3. **Non-Wage Preferences.** Officers receive different amenity value from working overtime, reflecting both classic leisure preferences and perhaps different average enjoyment from special events, which include a different set of tasks than the normal work day (traffic direction rather than parking enforcement) and also frequently involve celebrities.

To quantify the contribution of each channel, we shut down combinations of channels and compute the expected number of overtime shifts worked by each officer. We then compute the share of overtime worked by the top 10% of officers and compare it to the observed share. When shutting down each channel, we keep the expected number of overtime shifts worked constant by adding the appropriate constant to each officer-date's utility. If $u_{i,t}$ is the deterministic part of utility after the appropriate channels are shut down, the appropriate constant, call it c^*, solves the following equation:

$$\sum_{i=1}^{N}\sum_{t=1}^{T}\Phi(u_{i,t}+c^*) = \sum_{i=1}^{N}\sum_{t=1}^{T}W_{i,t}$$

Because the expected number of shifts worked by each officer is non-linear in the various channels, the order in which channels are shut down is important. For this reason we present three measures. First, we compute the change in inequality from just shutting down the focal channel but keeping the other two channels active. Second, we compute the change in inequality from shutting down all channels except the focal channel. Finally, we compute a Shapley decomposition meant to capture the average impact of shutting down the focal channel across all possible initial sets of active channels. Specifically, we equally weight the change from shutting down the focal channel from all four of the possible initially active channels: all channels active, focal channel and non-focal channel 1 active, focal channel and non-focal channel 2 active, only the focal channel active. We present the results in Table 8.

Several patterns emerge. First, the informal network is responsible for only a small amount of inequality. Second, non-wage preferences are the main driver of observed inequality, and removing preference differences but keeping all other differences intact would reduce the share of overtime worked among the top 10% of officers by 8.3 percentage points, which is large relative to the observed share of 31.5%. Third, wages differences that come through differences in tenure tend to reduce inequality: equalizing officer wages would increase inequality in overtime.

The decomposition exercise reveals that eliminating access differences due to informal networks is unlikely to noticeably improve overtime inequality. Indeed, the exercise suggests that it may increase inequality. Table 8 shows that when non-wage preferences are left unchanged but the other two channels are shut down, the share of overtime worked by the top 10% of officers rises by 4 percentage points.

Table 8: Decomposing Overtime Inequality

Channel	Remove All Others	Remove Just Channel	Shapley Average
Informal Network	-0.111	-0.007	-0.002
Non-Wage Preferences	0.040	-0.083	-0.040
Wages	-0.082	0.039	0.021

7 Counterfactuals

This section compares the status quo of informal trading to two counterfactual shift auctions. We show that informal trading has the same allocative efficiency as a uniform-markdown auction where officers are advantaged by their initial position in the union-negotiated wage scale. It also generates similar inequality and worker surplus. Compared to a uniform-wage auction, where officers are free to bid any wage, informal trading is less allocatively efficient and delivers less worker surplus but generates less inequality. In terms of the total overtime wage bill, both auction formats reduce the wage bill, but the reduction is modest and not much larger than the value of the access costs removed. We show that these results point to a fundamental trade-off between inequality and allocative efficiency. Allocations that minimize inequality require reducing allocative efficiency by $4 million in earnings equivalents.

7.1 Overtime Assignment Mechanisms

We consider three assignment mechanisms. In all counterfactual simulations, we do not incorporate dynamic worker behavior. Specifically, we do not adjust potential supplier count based on who works in each simulation, and our preference specification does not incorporate dynamic preferences for overtime.

7.1.1 Informal Trading

The status quo is an informal trading system. As this is the system under-which the observed data are generated, we discuss it extensively in Section 2. We use our estimated model to simulate informal trading. We redraw the idiosyncratic utility shocks $\epsilon_{i,t}$ from a standard logistic distribution 2,500 times. For each draw we assume an officer works overtime if the utility shock plus the estimated portion of utility is greater than 0.

7.1.2 Uniform-Wage Shift Auctions

The first alternative overtime assignment mechanism we consider is a uniform-wage shift auction. On each date t, the LADOT auctions k_t overtime slots, where k_t is the number of officers working overtime in the data on date t. On each date, all active officers simultaneously submit one sealed wage bid.[15] The officers that submit the lowest k_t wage bids are assigned the shift, and they are paid the $k_t + 1$ lowest wage, i.e. the first wage that did not win. This is a uniform-wage shift auction because all officers who work on date t are paid the same overtime wage.

We assume that since the informal secondary market is replaced by an auction, the access cost of obtaining a shift is 0. We implement this in our specification by setting $A_{i,t} = 0$ for all officers on all dates. Thus it is as if all officers are being directly given a shift by the wheel if they bid a low enough wage. Because $A_{i,t}$ multiplies potential suppliers in our specification of access costs, this also shuts down all variation in access costs across officers.

We now solve for the equilibrium bidding strategies of officers. Regardless of what others do, each officer's weakly dominant strategy is to bid the negative of their valuation. To see this, consider an officer with valuation x, denominated in wage equivalents, who bids

[15] Although this is a multi-unit auction we assume that each officer can work at most one overtime shift per date.

wage $-x$. Fix the $k+1$ lowest wage bid at y. First, suppose $-x < y$. In this case, the officer wins the shift and receives wage y obtaining positive utility $y + x > 0$. Any change of bid that is not greater than y has no impact on outcomes and leaves the officer indifferent. Bidding strictly above y causes the officer to no longer win the shift, strictly decreasing utility. Second, suppose $-x \geq y$. In this case, the officer does not win the shift and obtains utility 0. All alternative bids greater than y have no impact on outcomes and leave the officer indifferent. Any bid x' strictly below y causes the officer to win the shift, receive wage y and obtain negative utility because $y + x' < y + x \leq 0$.

As a result, officers will bid the negative of their valuation, and the officers with the k highest non-wage valuations for overtime will work overtime. We run this auction for each date in the sample among all active officers drawing $\epsilon_{i,t}$ from a standard logistic distribution. We set k, the number of shifts to be assigned each date, to be exactly the number of overtime shifts observed in the data on that day. We simulate the auction 2,500 times. We use exactly the same procedure to simulate the uniform-markdown shift auction discussed in the next subsection.

7.1.3 Uniform-Markdown Shift Auctions

Uniform-markdown shift auctions are identical to uniform-wage shift auctions, except that officers bid a markdown from their status quo overtime rate.[16] The officers who submit the lowest k_t wage markdown bids are assigned the shift, and they are paid their status quo overtime rate less the $k_t + 1$ largest wage markdown, i.e. the first markdown bid that did not win. This is a uniform-markdown shift auction because all officers who work on date t are paid the same markdown from their status quo wage but are not paid the same wage.

Truthful Bidding. In a uniform-markdown shift auction, officers continue to bid their true value for the shift as under a uniform-wage shift auction. We provide a proof in Appendix Section A, but the argument is very similar to the one provided for uniform-wage shift auctions. The key strategic difference between uniform-wage and uniform-markdown auctions is that officer valuations for the same overtime shift are different under each format, meaning that who wins and works the shift will be different under each system.

Preservation of Pay Scale. A feature of uniform-markdown shift auctions is that they preserve the status-quo differences in wages across officers. In our setting, these differences are due to the seniority-based pay steps negotiated by the union and outlined in the MOU with the City of Los Angeles. The pay steps are preserved because all the officers who win the auction on a particular date are paid the same markdown from their status quo wage.

[16] The status quo rate is 1.5 times their base rate, which comes from a union-negotiated pay scale.

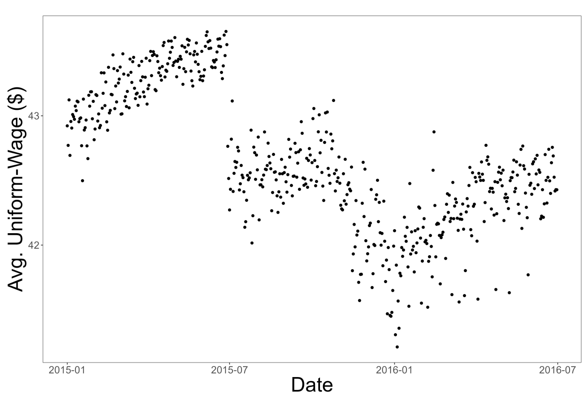
This feature also implies that, relative to a pure shift auction, the uniform-markdown shift auction implicitly advantages senior officers with a higher pay scale. For this reason, we view the uniform-markdown auction as more feasible than the uniform-wage auction.

7.2 Market-Clearing Wage Patterns

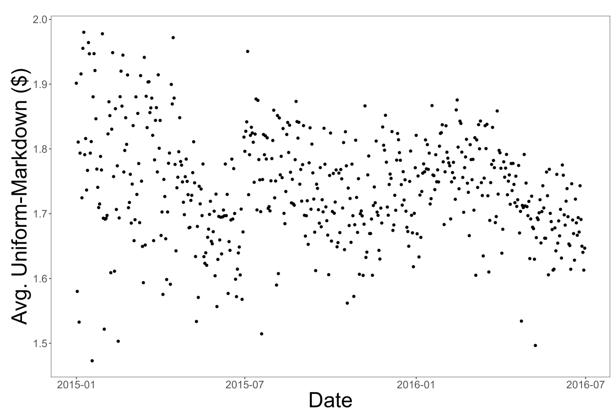
For each date t, we can compute the markdown that would be paid to all officers under a uniform-markdown auction (m_t) and the wage that would be paid to all officers under a uniform-wage auction (w_t). We present the average of each of these quantities across all simulations for each date in Figure 14.

We can interpret the equilibrium wage paid on each date as the exact wage which would balance supply and demand for overtime in a Walrasian equilibrium where some officers were initially endowed with overtime. Because w_t is exactly the value of overtime for the marginal officer (the first non-winner), any wage above w_t would create excess demand for overtime, and a wage that is too far below w_t (specifically that is below the valuation of the next officer) will create excess supply. In the same way, the equilibrium markdown is the exact markdown that would balance supply and demand for overtime in a Walrasian equilibrium where some officers were initially endowed with overtime, and officers are paid their specific base rate if they end up working the shift. Both therefore represent an equilibrium price of overtime when the frictional informal market is replaced with a frictionless formal market.

Figure 14: Equilibrium Wage and Markdown Patterns



(a) Uniform-Wages



(b) Uniform-Markdowns

Under this interpretation, the patterns we observe in Figure 14 represent the aggregate preference for overtime across the traffic officer workforce. The large reduction in the equilibrium wages and large increase in markdowns around July 1st, 2015 likely reflect the fact that a cohort of new traffic officers is added to the overtime pool at the turn of the fiscal year. If the LADOT knew m_t or w_t, it could implement the exact allocation of overtime as the auction by offering m_t or w_t to any officer that volunteered to work. Despite this, the auction serves an important role of helping the LADOT discover what m_t or w_t are in the first place, by providing an incentive for officers to truthfully bid their value for overtime.

7.3 Allocative Efficiency and Overtime Inequality

We now study how each system impacts overtime inequality and allocative efficiency. We measure allocative efficiency as the total non-wage utility of those who work overtime under an allocation. That is for an allocation $W = \{W_{i,t}\}_{i=,t=1}^{N,T}$ allocative efficiency is

$$E(W) := \sum_{i,t} W_{i,t} \cdot (X_{i,t}' \beta_2 + \gamma_t + \alpha_i + \epsilon_{i,t}).$$

Our measure intentionally excludes transfers (wages) and access costs incurred during informal trade to focus only on the non-wage utility obtained by workers from each overtime opportunity. We first highlight that because the uniform-wage auction always assigns overtime to the officers with the highest non-wage utility from overtime, it achieves the maximum allocative efficiency for any fixed number of overtime shifts.

We measure inequality by computing the share of overtime shifts assigned to the top 10% of officers. A more equitable system distributes a smaller share of overtime to the top 10% of officers. We display the results in Table 9. On average, the maximum allocative efficiency is -\$8,862,540. One interpretation of this number is that on average \$8,862,540 is the minimum earnings the LADOT must pay to officers to make them willingly supply the observed amount of overtime.

Table 9: Inequality and Allocative Efficiency under Different Mechanisms

	Allocative Efficiency			Share OT by Top 10		
Assignment Mechanism	p5	Mean	p95	p5	Mean	p95
Uniform-Markdown Auction	\$-9,160,690	\$-9,145,035	\$-9,129,379	0.311	0.314	0.317
Uniform-Wage Auction	\$-8,877,267	\$-8,862,540	\$-8,848,369	0.343	0.345	0.348
Informal Trading (Status Quo)	\$-9,195,039	\$-9,133,159	\$-9,072,472	0.314	0.317	0.319

One of the main trade-offs of uniform-wage auctions is also made apparent. Uniform-wage auctions increase allocative efficiency by \$270,619 by assigning overtime to the officers with the least disutility from work. But because preferences are very different across officers, this generates a large increase in overtime inequality, with the top 10% of officers working 34.5% of all overtime compared to 31.7% under informal trading or 31.4% under uniform-markdown auctions. Once again, the uniform-markdown auction and the informal trading appear similar in aggregate, with similar allocative efficiency and inequality levels. How well do the allocations from these systems compare to the best possible assignment, in terms of allocative efficiency and inequality?

Ideally, we would construct an inequality-efficiency frontier by maximizing allocative efficiency $E(W)$ given some maximum allowable inequality. However, that maximization problem is known to be computationally intractable even for a few agents, and we have several hundred.[17] Instead, we randomly allocate shifts to active officers on each date. We then allow a hypothetical manager to make progressively more adjustments to the roster of officers working. The manager's goal is to increase allocative efficiency, and the manager is constrained by the number of swaps they are allowed to make on each date. To be consistent with the auction counterfactuals, we do this for 2,500 draws of the idiosyncratic preference shocks $\epsilon_{i,t}$. For each draw of the preference shocks, we also randomly draw an initial allocation. We average the 2,100 estimates of inequality and allocative efficiency for each number of swaps given to the manager, generating 6,000 points that vary from 0 adjustments (random assignment) to over 260 million.[18].

We plot our approximation of the frontier in Figure 15, along with the average estimates obtained under the two counterfactual shift auctions and informal trading. Three patterns emerge. First, the frontier is convex and increasing. Particularly near the allocative efficiency delivered by the auctions, improving allocations requires assigning more and more overtime to the top 10% of officers. Second, all systems are not on the frontier. For each mechanism, there exist alternative allocations that on average achieve the same allocative efficiency with less inequality. Finally, informal trade and uniform-markdown auctions are very similar in terms of inequality and allocative efficiency.

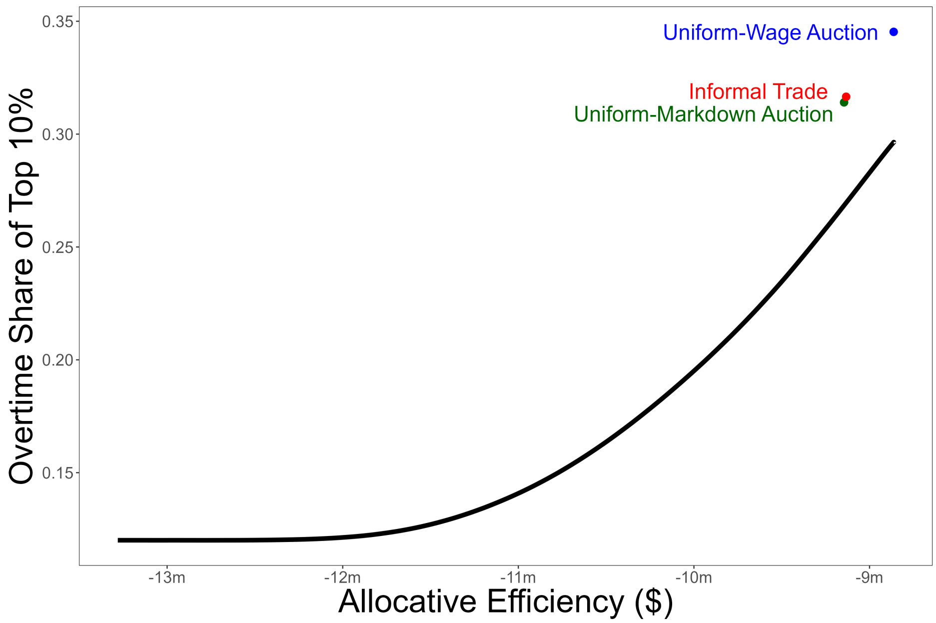
The equity-efficiency trade-off that comes from switching from informal trade to uniform-wage auctions is roughly equal to the equity-efficiency trade-off along the frontier. Specifically, if the LADOT started at the point on the frontier with the same allocative efficiency as informal trade and moved to the point on the frontier with the same allocative efficiency as uniform-wage auctions, the share of overtime assigned to the top 10% of officers would rise by 0.0324. This is very similar to the inequality gap between informal trade and uniform-wage auctions, which is 0.0316. This suggests that the comparison of uniform-wage auctions with informal trading captures a fundamental tension between equity and efficiency.

We can use the maximum allocative efficiency achieved by a uniform-wage auction and

[17]See Aziz et al. 2023.

[18]For additional details, see Appendix Section B.

Figure 15: Equity-Efficiency Frontier



the allocative efficiency achieved by random assignment to assess the performance of the informal trading system. Switching from random assignment to the uniform-wage auction increases allocative efficiency by $4.42 million in earning equivalent terms. Switching from random assignment to informal trading increases allocative efficiency by $4.15 million, which is 93.8% of the maximum possible gains.

7.4 Wages and Worker Surplus

Although informal trading, uniform-wage and uniform-markdown auctions achieve similar allocative efficiency, how they impact workers and the LADOT also depends on wages. For this reason, we consider how each system impacts the total wage bill and worker surplus. For each system, we report the 5th percentile, the mean, and the 95th percentile across all simulations in Table 10.

Table 10: Wage Costs and Worker Surplus under Different Mechanisms

	Overtime Wage Costs			Worker Surplus		
Assignment Mechanism	p5	Mean	p95	p5	Mean	p95
Uniform-Markdown Auction	$10,646,313	$10,661,039	$10,675,189	$1,503,097	$1,514,711	$1,526,197
Uniform-Wage Auction	$10,522,571	$10,535,861	$10,549,588	$1,654,521	$1,666,362	$1,678,521
Informal Trading (Status Quo)	$10,992,596	$11,066,211	$11,142,173	$1,516,755	$1,531,084	$1,545,347

Three patterns are worth noting. First, the uniform-wage auction results in the lowest wage costs and the greatest worker surplus. This is not surprising, as the uniform-wage auction assigns shifts to officers with the least disutility from working them and extracts surplus from workers via the lower wages. The wage cost reduction from moving from the status quo to uniform-wage auctions is $530,350 or -4.79%. This is not much larger than the access costs paid by those who work overtime under informal trading in the data, which are estimated to be $398,077. Since these access costs are removed under under the auction formats, the wage savings largely represent the LADOT extracting the access cost savings. The increase in worker surplus is $135,278 or 8.84%. This is modest: it is equivalent to paying each officer $0.55 more per hour for overtime, relative to an initial average overtime wage of $44.98.

Second, the uniform-markdown auction incurs higher wage costs and delivers less worker surplus than the uniform-wage auction because it advantages officers higher up on the pay scale, which requires paying higher wages and also distorts allocations. Still, switching from informal trading to the uniform-markdown auction reduces wage costs by $405,172 or 3.66%. This is 76.4% of the wage reductions achieved by the uniform-wage auction.

Third, informal trading delivers an average worker surplus higher than the average delivered by uniform-markdown auctions. There is overlap in the distribution of simulated outcomes in this case, meaning that we should be cautious about saying for sure which truly delivers more surplus. Note the uniform-markdown auction is delivering less surplus even though all access costs are set to 0 in the auction simulations. This is likely because the uniform-markdown auction is paying out less in wages to workers. Informal trading is therefore acting like a distorted auction from the perspective of workers. The main differences is that under a uniform-markdown auction the LADOT is extracting the access costs saved by workers through reduced wages. Because some of these access costs are in reality being paid to other officers as part of informal trades, the gap in worker surplus may be understated.

7.5 Impacts on Likely Cartel Members

Although the aggregate impacts of the counterfactuals are modest in some dimensions, the impacts on individual officers can be quite large. At a high level, uniform-wage shift auctions transfer worker surplus from officers that do not value overtime to officers that do value overtime. We illustrate this by showing the estimated overtime shifts, overtime pay, and worker surplus of the 10 likely cartel members in Table 11. Switching to uniform-wage shift auctions reduces the worker surplus of the two likely cartel members that have weak preferences for overtime (smaller fixed effects) and increases the worker surplus of the eight likely cartel members that have strong preferences for overtime (larger fixed effects).

Table 11: Counterfactual Impacts on Likely Cartel Members

		Overtime Shifts			Overtime Pay			Worker Surplus		
Officer ID	FE Rank	Informal	Wage	Markdown	Informal	Wage	Markdown	Informal	Wage	Markdown
537	1	524	539	519	\$126,894	\$144,940	\$119,989	\$56,494	\$73,675	\$52,907
432	27	473	392	464	\$144,875	\$106,938	\$137,141	\$35,538	\$22,539	\$33,521
200	3	390	483	377	\$95,398	\$130,338	\$88,199	\$22,797	\$38,051	\$21,142
373	56	368	253	359	\$113,993	\$69,869	\$107,049	\$20,021	\$10,947	\$18,908
124	93	330	279	317	\$96,602	\$76,631	\$89,341	\$16,280	\$12,618	\$15,311
308	60	325	271	309	\$95,328	\$74,411	\$87,075	\$15,928	\$12,053	\$14,636
264	69	317	281	319	\$93,177	\$77,178	\$89,839	\$15,299	\$12,742	\$15,423
471	45	317	255	294	\$93,130	\$70,341	\$82,990	\$15,385	\$11,072	\$13,544
394	65	316	200	306	\$98,092	\$55,629	\$91,470	\$15,443	\$7,975	\$14,465
44	90	304	278	317	\$88,892	\$76,423	\$89,280	\$14,360	\$12,580	\$15,255

Officer 537 worked the most overtime in the data, and our estimates reveal this is due to both low access costs and a strong preference for overtime. As a result, officer 537 works similar amounts of overtime across all systems. Officer 537 is not very senior, and as a result is disadvantaged under a uniform-markdown auction and therefore prefers a uniform-wage auction. The effects of changing systems varies dramatically officer by officer. One officer works over 100 fewer shifts under a uniform-wage auction compared to informal trading, while another works almost 100 more. All members of the cartel would still earn more than \$50,000 under both counterfactual auctions, with several increasing their overtime pay.

8 Discussion and Robustness

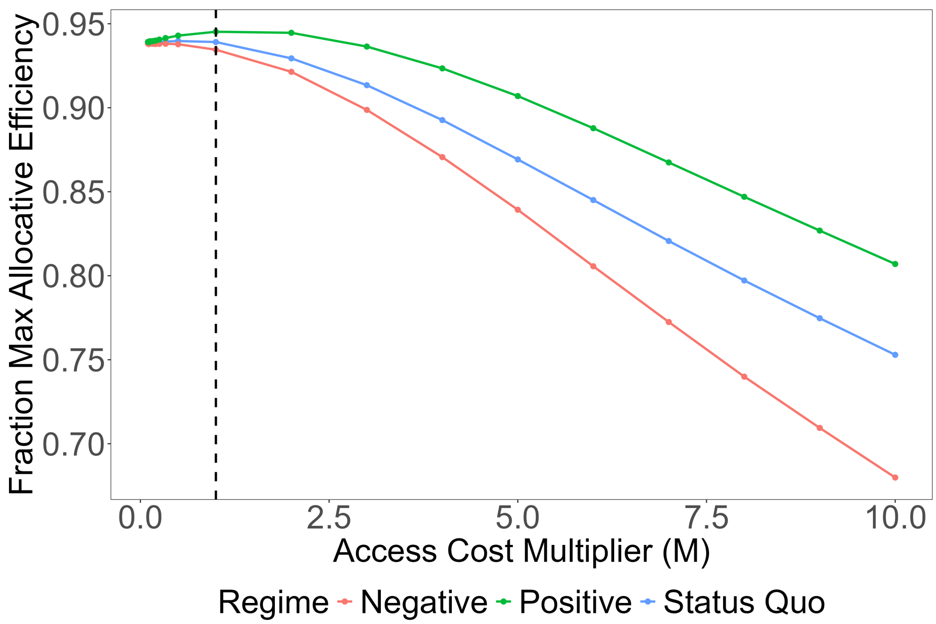
This section considers our results in light of several concerns, including underestimation of access costs, productivity implications for the organization, and the threat of collusion by members of the alleged "cartel." We also discuss analyze the reasons why informal trade performs well in our setting, by performing a series of analyses where access costs are permuted, scaled up, and scaled down.

8.1 Understanding the Efficiency of Informal Trading

We find that an informal and frictional overtime assignment mechanism achieves similar allocative efficiency as formal and frictionless auctions. In this section, we perform an additional exercise that allows us to understand what drives this result, and whether the result is robust.

Specifically, we change the magnitude of access costs by introducing a multiplier M to access costs: $M \cdot A_{i,t}(\beta_2 + \beta_3 Z_{i,t})$. We vary M from 1/10 (10 times smaller access costs) to 10 (10 times higher access costs). We also vary the link between potential suppliers and officer preferences. We consider three regimes. In the positive assortative regime, we reassign the highest number of potential suppliers on each date to the officer with the highest fixed-effect. In the status quo regime, we keep the data as is. In the negative assortative regime, we reassign the highest number of potential suppliers on each date to the officers with the lowest fixed-effect. We perform every combination of access cost magnitude and regime, and compute the average allocative efficiency over 2,500 simulations. To keep the expected number of overtime shifts constant, we apply the adjustment described in Section 6. The results are depicted in Figure 16, where allocative efficiency is measured as a percentage of the gap in allocative efficiency between random assignment and the maximum achieved by a uniform-wage shift auction. The dashed line indicates a multiplier of 1, which corresponds to the actual access costs we estimate.

Figure 16: Robustness to Access Cost Magnitude and Correlation



We first use the results to show robustness. Our headline result, that informal trading achieves 93.8% of the maximum possible allocative efficiency, corresponds to the intersection of the dashed line with the blue status quo line. If we triple the magnitude of access costs, allocative efficiency decreases by only 2.5 percentage points. Thus, if access costs are underestimated because of measurement error or contamination of costs with preferences, the underestimation must be very large in order to meaningfully change the allocative efficiency of informal trading. A similar result obtains if we reduce access costs by a factor of 3. If we fix the access cost multiplier and switch to either the positive or negative regime, the average allocative efficiency remains between 93.4% and 94.5%. Thus, if we incorrectly estimated the correlation between potential supplier count and preferences, this would not have a noticeable impact on our headline result.

We next use the results to interpret the reason why informal trade is relatively efficient. In the positive regime, the network essentially encodes the preferences of officers: we have rearranged the data so that those that desire overtime also have many potential suppliers. As a consequence, halving access costs by moving from $M = 1$ to $M = 1/2$ actually reduces allocative efficiency. In the negative regime, the network is essentially constructed to block the officers who most want overtime form obtaining it: we have rearranged the data so that those who desire overtime have the least potential suppliers. As a consequence, halving access costs increases allocative efficiency. The status quo regime lies between these cases: the actual network partially encodes the preferences of officers, and as a result halving access costs by moving from $M = 1$ to $M = 1/2$ has almost no impact on allocative efficiency.

As the multiplier rises beyond 1, allocative efficiency falls across all regimes. At first, increasing access costs by a factor tends to have a larger impact on efficiency than changing regimes, but once access costs become large enough, switching regimes begins to have a significant impact. For example, when $M = 10$, switching from the status quo to the positive regime where potential supplier count is perfectly correlated with officer fixed effects increases efficiency by 5.40 percentage points, while switching to the negative regime where potential supplier count is perfectly negatively correlated decreases efficiency by 7.30 percentage points. The synergy between regime change and access cost magnitude has a simple intuition: encoding the network with officer's preferences matters more when the barriers to trade are large.

Putting all of this together, informal trade makes efficient allocations both because the network partially encodes officer preferences and because access costs are small in magnitude. The online forum combined with a relative thick market for overtime are two potential reasons why access costs are small. One potential reason the network encodes preferences is that officers become better connected by working more, and the main way to work more is to obtain special event overtime. Put another way, an officer gains a potential supplier by working alongside someone they do not typically work alongside, and this happens primarily by working a special event. Thus, the fact that the trade network is endogenously formed by past trade results in efficient allocations. Whether we should expect informal trade of overtime to be allocatively efficient in other settings depends on whether we expect access costs to be small and trading ability to be correlated with overtime preferences.

8.2 Overtime Assignment and Productivity

Our results so far focus on the wages and worker surplus implied by different overtime assignment mechanisms. An equally important question for the organization is how the different mechanisms impact productivity. Specifically, how does the selection of officers by each overtime assignment mechanism shape the effective productivity of the overtime workforce? In this section we develop a measure we believe to be associated with officer productivity, and show suggestive evidence switching from the status quo to uniform-wage auctions would reduce productivity while switching to uniform-markdown auctions would slightly improve productivity. We interpret our results from this exercise as suggestive and not causal because the statistical power of our estimates is low and the identification assumptions needed for causality are strong.

Traffic officers perform two broad tasks: directing traffic and enforcing parking laws. Special events and therefore overtime shifts primarily involve traffic direction.[19] We therefore focus on constructing a measure that captures how productive officers are at directing traffic.

We measure the overall daily special event traffic direction productivity of the LADOT, Y_t, using the number of collisions within 400 meters of all BSS permitted special events that occurred on date t.[20] We can do this because all special events using BSS special-event permits list an address for each event, and all collisions reported by the LAPD are publicly recorded with location and date information. Between January 1, 2015 and June 30, 2016, 80,057 collisions are recorded in the data reported by the LAPD. Of these, 310 are within 400 meters of a special event. We exclude the one and only collision in the period that has an unrecorded location. We provide an explicit example of a collision near a special event in Appendix Section D.

We decompose overall daily productivity to obtain individual time-invariant officer safety productivity, denoted $\hat{\theta}_i$, using the approach developed in Bonhomme 2021. This approach is explained in Appendix Section C, and essentially assumes a productivity production function linear in individual productivity with identification achieved using variation in the composition of the officers working overtime on each date. Officers with a high safety productivity have a low $\hat{\theta}_i$ because when they work overtime the expected number of collisions is lower. We define the safety productivity of the LADOT under overtime allocation W as the sum of officer safety productivity multiplied by the number of shifts they worked: $\sum_{i,t} W_{i,t}\hat{\theta}_i$

We plot histograms of simulated traffic direction productivity in Appendix Figure 17

[19] The City of Los Angeles maintains a public database of parking citations and, during our analysis period, less than 1% of the citations are associated with special events.

[20] We use the Haversine distance between two coordinates to account for the curvature of the Earth.

under each of the three assignment mechanisms. Recall that smaller values represent greater productivity. Simulated traffic direction productivity is similar under informal trading and uniform-markdown auctions, with slightly better average productivity under a uniform-markdown auction (17 compared to 29). This is consistent with our earlier results that informal trading is similar in aggregate to uniform-markdown auctions. Traffic direction productivity is lower under uniform-wage auctions with an average of 107, and this appears to be because this mechanism does not favor more experienced officers.

8.3 A Potential Bidding Ring

There is a "cartel" of highly connected officers who obtain many overtime shifts under the status quo informal trading system. Will this cartel form a bidding ring if the LADOT switched to an auction system? Several forces point to yes. Special events would need to be auctioned frequently, giving rise to repeat interaction. Fairness concerns would likely require the LADOT to use an auction format, like the uniform-wage or uniform markdown, which are known to be susceptible to collusion than pay-your-wage bid alternatives (Robinson 1985). But several important forces point to no. First, there are many hundreds of bidders with highly dispersed valuations for overtime. Second, officers are geographically separated into divisions. Dispersion of values has been shown to make bidder collusion more difficult to maintain (Maskin and Riley 2000), while geographic separation makes communicating and enforcing complicated bidding strategies costly.[21]

If the original cartel can capture a centralized auction, the wages and non-wage utility delivered discussed in Section 7 are upper bounds on the effects of auctions relative to the status quo. Still, there are ways to mitigate collusion while still addressing fairness concerns. One option would be to randomly draw officers to participate in each auction. If the set of participants changes over time, collusive strategies will be harder to maintain. Such a strategy of rotating who competes with whom was used successfully among chicken growers (Knoeber 1989).

9 Conclusion

This paper uses the unique institutional details of Los Angeles traffic officers to study how the assignment of overtime influences various outcomes. We show that the status quo system,

[21] The auctions we consider are multi-unit with single-unit demand. Marszalec, Teytelboym, and Laksá 2020 describe how many of the intuitions described in single-unit settings extend to multi-unit auctions with multi-unit demand, but to our knowledge there is less work examining multi-unit auctions with single-unit demand.

which features informal bilateral trading, has similar allocative efficiency as a shift auction where workers bid markdowns from their status quo overtime wage. It is less allocatively efficient than a shift auction where officers bid wages directly, but it generates less inequality.

Several important related questions deserve additional study. First, to what extent do internal leave policies (sick banks, rolling holidays, parental leave, etc.) interact with how an organization should assign work? Second, to what extent is the demand for overtime by workers dynamic, and how does this influence the design of overtime systems? Third, how does the recruitment process of workers influence the correlation between overtime valuations and productivity? Answering these questions will require data similar to those used in this paper, along with additional structural modeling. Nevertheless, the answers to these questions are likely to be useful both in terms of designing policies within organizations and for understanding how dynamics within the firm influence macroeconomic outcomes, like total labor supply and labor demand.

References

Aziz, Haris et al. (2023). "Computing welfare-maximizing fair allocations of indivisible goods". In: *European Journal of Operational Research* 307.2, pp. 773–784.

Ba, Bocar et al. (2022). *Police Officer Assignment and Neighborhood Crime*. Tech. rep. National Bureau of Economic Research.

Bandiera, Oriana, Iwan Barankay, and Imran Rasul (2012). "Social Connections and Incentives in the Workplace: Evidence from Personnel Data". In: *Econometrica* 57.2, pp. 403–411.

Barron, Greg and Felix Vardy (2005). *The Internal Job Market of the IMF's Economist Program*. Tech. rep. 3, pp. 410–429.

Bonhomme, Stéphane (2021). "Teams: Heterogeneity, sorting, and complementarity". In: *arXiv preprint arXiv:2102.01802*.

City of Los Angeles (2023). *LADOT Parking Enforcement Districts*. https://geohub.lacity.org/datasets/lahub::ladot-parking-enforcement-districts/explore. Accessed: 2025-03-11.

City of Los Angeles Civil Service Commission (Sept. 2009). *Class Specification Traffic Officer 3214*. https://personnel.lacity.gov/perspecs/3214.pdf. Accessed 2025-07-11.

City of Los Angeles Personnel Department (2024). *Traffic Officer Task List (Class Code 3214)*. https://personnel.lacity.gov/doc.cfm?get=Task3214. Accessed 2025-07-11.

— (2025). *Career Ladders*. https://personnel.lacity.gov/jobs/career-ladders.cfm. Accessed 2025-07-12.

City of Los Angeles, Office of the City Administrative Officer (July 2015). *Memorandum of Understanding No. 18 (Safety/Security Representation Unit)*. https://cao.lacity.gov/MOUs/MOU18-18.pdf. Effective July 1, 2015 – June 30, 2018; accessed 2025-07-12.

Coase, Ronald H. (1993). "The nature of the firm (1937)". In: *Economica* 4, pp. 396–405.

Cowgill, Bo et al. (2024). "Stable Matching on the Job? Theory and Evidence on Internal Talent Markets". In: *Management Science* 71.3, pp. 2508–2526.

Davis, Jonathan M.V. (n.d.). "Labor Market Design Can Improve Match Outcomes: Evidence from Matching Teach for America Teachers to Schools". In: *Journal of Political Economy Microeconomics* (). to appear.

Davis, Jonathan MV, Kyle Greenberg, and Damon Jones (n.d.). *An Experimental Evaluation of Deferred Acceptance: Evidence from over 100 Army Officer Labor Markets*. Tech. rep. to appear.

Fernández-Val, Iván and Martin Weidner (2016). "Individual and time effects in nonlinear panel models with large N, T". In: *Journal of Econometrics* 192.1, pp. 291–312.

Galperin, Ron (June 2015). *DOT Traffic Control for Special Events*. URL: https://lacontroller.org/wp-content/uploads/2019/07/dotovertimespecialevents.pdf.

Knoeber, Charles R. (1989). "A real game of chicken: contracts, tournaments, and the production of broilers". In: *The Journal of Law, Economics, and Organization* 5.2, pp. 271–292.

LADOTOfficial (2018). *Roll Call at Hollywood Parking Enforcement*. Accessed: 2025-07-11. Los Angeles Department of Transportation. URL: https://www.youtube.com/watch?v=ix2fUs44qck.

Laverde, Mariana et al. (2023). *Gains from Alternative Assignment? Evidence from a Two-Sided Teacher Market*. Tech. rep. Working Paper.

Los Angeles Department of Building and Safety (2025). *Building and Safety Temporary Special Event (TSE) Permits*. Accessed: 2025-02-07. URL: https://data.lacity.org/City-Infrastructure-Service-Requests/Building-and-Safety-Temporary-Special-Event-TSE-Pe/8spw-3fhx/about_data.

Los Angeles Department of Transportation (2025). *Contact Us*. https://ladotparking.org/contact-us/#. Accessed: 2025-07-11.

Los Angeles Police Department (2025). *Traffic Collision Data from 2010 to Present*. Accessed: 2025-03-20. URL: https://data.lacity.org/Public-Safety/Traffic-Collision-Data-from-2010-to-Present/d5tf-ez2w/about_data.

Marszalec, Daniel, Alexander Teytelboym, and Sanna Laksá (2020). "EPIC Fail: How below-bid pricing backfires in multiunit auctions". In: *CIRJE Working Paper CIRJE-F-1096*.

Maskin, Eric and John Riley (2000). "Asymmetric auctions". In: *The review of Economic Studies* 67.3, pp. 413–438.

Minni, Virginia (2024). *Making the invisible hand visible: Managers and the allocation of workers to jobs*. Tech. rep. Working Paper.

National Oceanic and Atmospheric Administration (2019). *National Centers for Environmental Information*. Accessed: 2019-08-11.

Nelson, Laura J. (July 2015). "L.A. fails to collect from Oscars and other events for officer overtime pay, audit finds - Los Angeles Times". In: URL: https://www.latimes.com/local/lanow/la-me-ln-ladot-audit-overtime-20150701-story.html.

Parrish, Medgar (2020). *2 Way Intersection: Training video*. Accessed: 2025-07-11. Los Angeles Department of Transportation. URL: https://www.youtube.com/watch?v=JAzRB3olrb0.

Robinson, Marc S. (1985). "Collusion and the Choice of Auction". In: *The RAND Journal of Economics* 16.1, pp. 141–145.

Rosen, Sherwin (1988). "Transactions costs and internal labor markets". In: *The Journal of Law, Economics, and Organization* 4.1, pp. 49–64.

Sedacca, Matthew (June 2024). "Over 200 Port Authority cops make six figures — including one $400K earner — from staggering OT pay". In: URL: https://nypost.com/2024/06/15/us-news/port-authority-cops-in-nyc-earn-staggering-overtime-pay/.

Stammann, Amrei (2017). "Fast and feasible estimation of generalized linear models with high-dimensional k-way fixed effects". In: *arXiv preprint arXiv:1707.01815*.

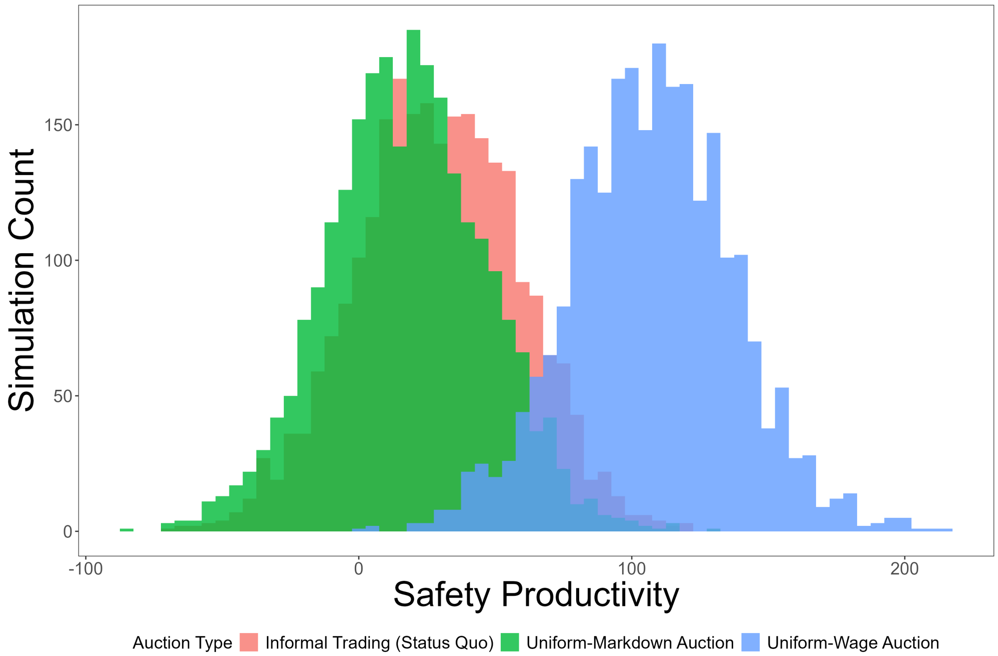
Tchekmedyian, Alene and Paul Pringle (Apr. 2025). "A Times investigation: LAFD union head made $540,000 in a year, with huge overtime payouts - Los Angeles Times". In: URL: https://www.latimes.com/california/story/2025-04-30/lafd-union-head-massive-amounts-of-overtime.

A Truthful Bidding under Uniform-Markdown Shift Auctions

Consider an officer with a non-wage valuation x and a statutory overtime wage of w. Their total valuation, denominated in wage equivalents, of the shift in a uniform-markdown shift auction will be $\tilde{x} := x/\rho + w$.

We wish to prove that it is weakly dominant for the officer to bid a markdown of $\tilde{x}$ even if all the bids of other officers are known. Fix the $k+1$ highest markdown bid to be y. First, suppose $\tilde{x} > y$. In this case, the officer wins the shift and has their wage marked

Figure 17: Simulated Safety Productivity



down by y obtaining positive utility because $\tilde{x} - y > 0$. Any change of bid not smaller than y has no impact on the officer's outcome and leaves the officer indifferent. Bidding a markdown strictly below y causes the officer to no longer win the shift, generating 0 utility and making the officer strictly worse off. Second, suppose $\tilde{x} \leq y$. In this case, if the officer does as we suppose and bids $\tilde{x}$, they do not win the shift and obtain utility 0. All alternative bids less than y have no impact on the officer's outcomes and leave the officer indifferent. Any markdown bid x' strictly above y causes the officer to win the shift and have their wage marked down by at least x'. This generates strictly negative utility because: $\tilde{x} - x' < \tilde{x} - y \leq 0$. Thus, it is a weakly dominant strategy for all officers to bid a markdown equal to their total valuation (which includes their statutory overtime wage).

B A Hypothetical Manager

We benchmark the status quo of informal trading as well as the two auction systems against a hypothetical manager who can make an increasing number of duty-roster adjustments. We first randomize the order of the list of officers active on each date. The hypothetical manager is then allowed to sort the list of officers according to the officer-specific outcome of interest (skill or overtime valuation), with two constraints. First, they can only compare and potentially swap officers adjacent in the ordered list. Second, they can make at most

s_t swaps on date t. After the swaps are complete, the first k_t officers on each date work overtime, where k_t is the number of overtime shifts observed in the data.

We start with $s_t = 0\,\forall t$, which implies the officers who work overtime are randomly selected. We then set $s_t = x$ for all t. We then set $s_t = 2 \cdot x$ for all t. Continuing on this way, we sequentially increase the number of swaps allowed on each date. A manager's total endowment of swaps is then given by $S = \sum_t s_t$. We repeat this process, randomizing the initial order of the list 2,500 times, and compute the average outcome for many different values of S. We set the incrementing step x to be 80. We set the incrementing step high because officer overtime preferences are so disbursed that it takes many swaps on each date to meaningfully change allocative efficiency. Thus even with an incrementing step of 80, it still takes significant computational resources to trace the frontier from the allocative efficiency from random assignment to the allocative efficiency from uniform-wage auctions.

C Constructing Officer Safety Productivity

This section outlines our method for constructing officer safety productivity. We link daily organization-wide productivity (Y_t) to individual productivity (θ_i) using the additive teamwork framework developed in Bonhomme 2021. We residualize Y_t for the number of officers working overtime as well as day of the week and month fixed effects, and denote the result $\tilde{Y}_t$. We then assume that each organization-wide productivity measure is the sum of the associated individual skill of all officers who worked overtime on date t plus an idiosyncratic term independent of the composition of the overtime workforce that day:

$$\tilde{Y}_t = \sum_i W_{i,t}\theta_i + \omega_{i,t}$$

On any given day, only some officers work overtime. We define the $T \times N$ matrix B, where entry $B_{t,i}$ is 1 if officer i works overtime on date t and 0 otherwise. We denote e_i as a vector that is 0 everywhere except entry i, and we define $ginv(\cdot)$ as the Moore-Penrose generalized inverse of a matrix. Bonhomme 2021 shows that variation in team composition identifies the individual skill θ_i of an officer i if and only if

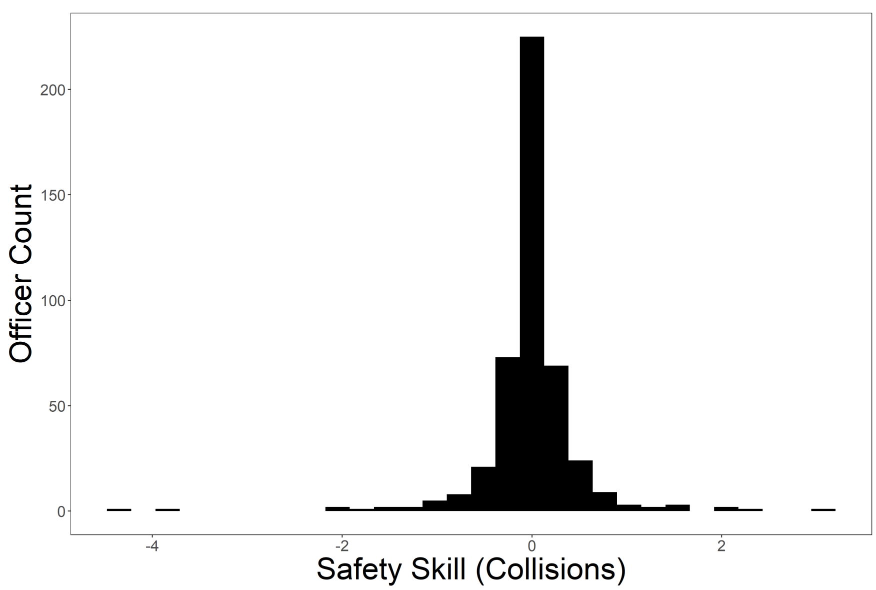
$$[I - B' ginv(B')]e_i = 0.$$

We begin by identifying all officers that do not satisfy this condition. Intuitively, these officers do not work with enough distinct sets of coworkers to isolate their individual productivity. We remove these officers and all dates on which they work overtime and then check the condition among the new subset. We repeat this process until convergence, removing 33 officers, and leaving only identified officers and the dates where only identified officers work. Denote the team composition matrix constructed from removing these officers and dates as $\tilde{B}$. Again following Bonhomme 2021, we estimate individual safety skill as

$$\begin{bmatrix} \hat{\theta}_1 \\ . \\ \hat{\theta}_i \\ . \\ \hat{\theta}_N \end{bmatrix} = (\tilde{B}'\tilde{B})^{-1}\tilde{B} \begin{bmatrix} \tilde{Y}_1 \\ . \\ \tilde{Y}_t \\ . \\ \tilde{Y}_T \end{bmatrix}$$

We plot the distribution of safety skill in Figure 18. Safety skill can be interpreted as follows: substituting an officer with a safety skill of 0 with an officer with a safety skill of -0.5 reduces the expected number of collisions near special events by 0.5.

Figure 18: Histogram of Estimated Officer Safety Skill ($\hat{\theta}_i$)

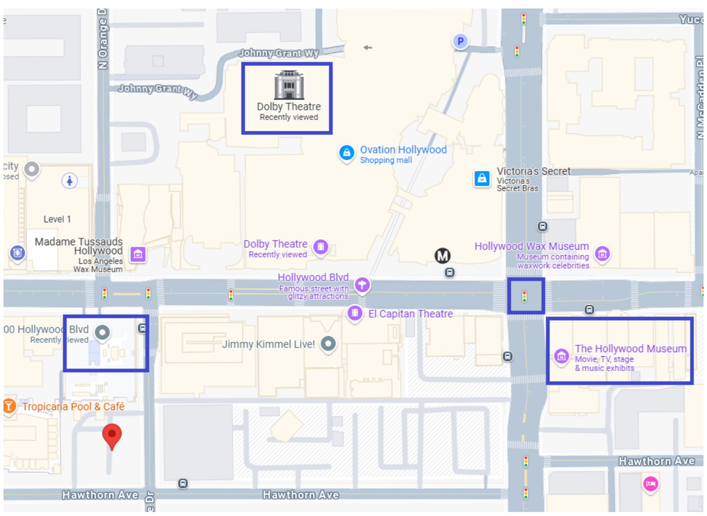


The correlation between an officer's connectedness and safety skill is 0.007. Since connectedness is an important determinant of who works overtime under the informal trading system, Fact 5 suggests that the current system does not positively or negatively select officers into overtime. In some sense this finding is not surprising: the system was not designed to sort officers based on skill. This fact suggests that changing the assignment mechanism could improve productivity by distributing overtime work to more skilled officers.

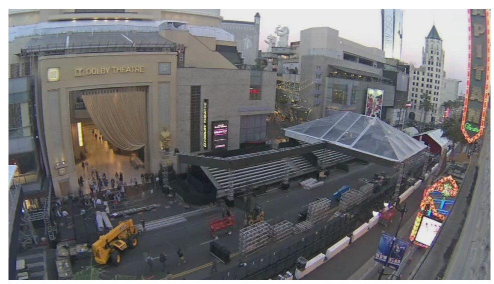
D A Collision Near the Oscars

To make our definition of traffic direction productivity concrete, we provide an example in Figure 19. The 87th Academy Awards (Oscars) were held on Sunday February 22, 2015 and four Special Event Permits were issued for the four locations marked in blue. The Oscars were held at the Dolby Theatre. Several structures, including bleachers, were set up in the intersection of Hollywood Boulevard and Highland Ave, marked in blue. Many streets surrounding the Dolby Theatre were closed and traffic redirected, in the days and hours leading up to the Oscars. 105 officers worked overtime the day prior to the Oscars, and 84 worked overtime the day of the Oscars. At 11:30AM on February 22, 2015, near the location marked with red, a vehicle-on-vehicle collision occurred. This location is within 200 meters of the Dolby Theatre, and we therefore count it when computing overall traffic direction productivity.[22]

Figure 19: A Collision Near the Oscars



(a) Map of Collision and Special Events



(b) Road Closure and Setup

Note. The left panel depicts a map of the special events associated with the Oscars on February 22, 2015, as well as a nearby collision. The right panel, which is a still image taken from a time lapse compiled by 6 ABC Action News, shows the road closure and setup outside the Dolby Threatre in preparation for the Oscars.

[22] A time lapse video of the setup of the Oscars, which occurred over several days, is available here: https://6abc.com/2015-oscars-red-carpet-hollywood-boulevard-dolby-theatre/527980/.

Table 12: Alternative Specifications with Lagged Overtime and Normal Work

Variable	Estimate (Logit)	APE (Logit)	Estimate (Probit)	APE (Probit)
Distance from Wheel	-1.514	-0.145	-0.838	-0.142
	(0.110)	(0.007)	(0.060)	(0.007)
Normal - Lag 1	0.139	0.013	0.080	0.013
	(0.031)	(0.002)	(0.017)	(0.002)
Normal - Lag 2	-0.015	-0.001	-0.006	-0.001
	(0.023)	(0.002)	(0.013)	(0.002)
Normal - Lag 3	-0.040	-0.004	-0.020	-0.003
	(0.021)	(0.002)	(0.012)	(0.002)
Normal - Lag 4	-0.009	-0.001	-0.004	-0.001
	(0.022)	(0.002)	(0.012)	(0.002)
Normal - Lag 5	-0.038	-0.004	-0.020	-0.004
	(0.022)	(0.002)	(0.012)	(0.002)
Normal - Lag 6	-0.030	-0.003	-0.018	-0.003
	(0.025)	(0.002)	(0.014)	(0.002)
Normal - Lag 7	-0.063	-0.006	-0.037	-0.006
	(0.025)	(0.002)	(0.014)	(0.002)
Normal Work	0.190	0.018	0.101	0.017
	(0.044)	(0.002)	(0.024)	(0.002)
OT - Lag 1	0.705	0.075	0.418	0.080
	(0.032)	(0.002)	(0.018)	(0.002)
OT - Lag 2	0.245	0.024	0.148	0.026
	(0.024)	(0.002)	(0.014)	(0.002)
OT - Lag 3	0.089	0.009	0.056	0.010
	(0.024)	(0.002)	(0.014)	(0.002)
OT - Lag 4	0.067	0.006	0.042	0.007
	(0.024)	(0.002)	(0.014)	(0.002)
OT - Lag 5	0.138	0.013	0.084	0.015
	(0.021)	(0.002)	(0.012)	(0.002)
OT - Lag 6	0.350	0.035	0.206	0.037
	(0.023)	(0.002)	(0.013)	(0.002)
OT - Lag 7	0.676	0.072	0.403	0.076
	(0.031)	(0.002)	(0.018)	(0.002)
Overtime Wage	0.165	0.016	0.093	0.016
	(0.029)	(0.001)	(0.014)	(0.001)
Seniority Rank	0.006	0.001	0.004	0.001
	(0.010)	(0.000)	(0.006)	(0.000)
Supplier Count x Distance from Wheel	0.021	0.002	0.012	0.002
	(0.004)	(0.000)	(0.002)	(0.000)

Note: Standard errors are clustered at the officer level. We present alternative model specifications with lagged overtime and normal work indicators. We include a week of lagged terms.