

What happens when the police go on strike? Homicides increase. Evidence from Ceará, Brazil

Abstract

This study investigates how an abrupt reduction in policing impacts upon the occurrence of homicides in a violent context in the Global South. The study utilizes a police strike in the Brazilian state of Ceará in summer 2020 as a quasi-natural experiment. Separate SARIMA and Exponential Smoothing models fitted on data on weekly homicide counts from January 2015 to the beginning of the strike are used to generate forecasts of homicides in a virtual counterfactual scenario with no police strikes. Actual homicide counts and forecasts are subsequently compared. The strike led to a statistically significant increase in homicides ranging between 110% and 250%. A difference-in-differences analysis confirms this result. The elasticity of homicides with respect to police presence is tentatively estimated at between -1.5 and -5.0. Even in a violent context, the perception of a higher risk of apprehension induced by police presence acts as a powerful deterrent against homicides.

Keywords

Lethal violence; Crime forecast; Quasi-Natural Experiment; Deterrence; De-policing; COVID-19

Introduction

Beccaria (2016 [1764]) and Bentham (1988 [1789]) were the first to identify the severity, certainty, and celerity of punishment as the cornerstones of crime deterrence. Two and a half centuries after the publication of their seminal treatises, these ideas, particularly those concerning the certainty and severity of the sentence, are still central tenets of almost all theories of deterrence. In contemporary democratic societies, the police constitute the foundation of the ‘certainty’ component of crime deterrence (Nagin 2013). In this respect, we now know that the adoption of hot-spot and problem-oriented policing can be effective in preventing drug offenses, disorder offenses, and other crimes (Braga et al. 2019; Hinkle et al. 2020). However, there remains a question concerning the extent to which police presence in and of itself reduces crime (Kovandzic et al. 2016). It is difficult to draw definitive conclusions in this regard because all forms of nonexperimental design are vulnerable to reverse causality issues (Farrington et al. 2020). That is to say, while greater police levels may indeed reduce crime, growing crime rates can also lead to more police presence as a result of both increased public attention and more resources being devoted to combatting crime. Moreover,

additional police might cause crime to increase on paper by detecting more crimes (Kovandzic et al. 2016; Nagin 2013).

Moreover, while scholars' attention to the impact of police presence on crime has been high in the Global North, particularly in the USA, there remains a relative dearth of studies on the relation between police presence and crime in other contexts. In their systematic review of the effectiveness of police presence, Dau et al. (2021) identify only three studies conducted in the Global South (6.1% of all the studies reviewed). This knowledge gap is significant because the criminogenic conditions in the Global South often differ from those in the USA or other advanced economies. In particular, violent crime rates are higher in Latin America than in the rest of the world (Muggah and Tobón 2019). At the same time, the region is characterized by endemic corruption, while criminal groups develop symbiotic relations with police authorities (Goldstein and Drybread 2018; Magaloni et al. 2020; Mantilla and Feldmann 2021). Moreover, in several Latin American countries, extralegal violent actors and organized criminal groups compete with legitimate institutions to provide security governance to the most disadvantaged communities, thus impacting on the relationship between the police presence and the occurrence of crimes (Aziani et al. 2020; Mantilla and Feldmann 2021). Analysis of the relation between police presence—or absence—and crimes in the Global South would yield better understanding of the extent to which the interpretations of criminal dynamics that are currently used to explain crime in advanced economies are also suitable for explaining crime in other regions and contexts. Such an understanding would aid attempts to design more calibrated crime reduction policies for countries in those regions where crime and violence impose a greater strain on society at large—particularly on its most vulnerable constituents.

Starting from these premises, this study utilizes a police strike that occurred in the Brazilian state of Ceará between February and March 2020, and which cut the police presence roughly by half, as a quasi-natural experiment through which to assess the extent to which a marked decrease in policing impacts upon a serious crime like homicide. In most societies, the likelihood of observing natural episodes of sharp decreases in policing is slim because societies go to great lengths to avoid such events due to the crucial role played by the police in preserving the rule of law (Benzaquen 2021). At the same time, evaluating the impact of an abrupt reduction in policing in an experimental setting is seldom a viable option, because setting up randomized control trials on such vital issues encounters manifold ethical and organizational obstacles (Farrington et al. 2020). Given these methodological challenges, the occurrence of police strike action provides a rare opportunity to observe changes in crime in response to a reduction in policing.

The Brazilian context is of especial interest for examining the relationship between police presence and violent crimes for several reasons. Firstly, both the prevalence of violence and the high murder rate are particularly pressing problems in Brazil (Kopittke and Ramos 2021). In 2018, authorities recorded 57,358 homicides in the country, with an average of more than 157 murders per day. This level of violence means that Brazil has one of the highest homicide rates (23.6 per 100,000 inhabitants) in the world; indeed, the homicide rate is comparable to that of countries where actual armed conflicts are taking place (FBSP 2021). At the same time, Brazilian society also faces several challenges with respect to policing. Instances of illegitimate violence committed by the police are frequent, racial discrimination by police forces remains an unsolved issue, while the Brazilian police has a long history of strike actions and riots (Alcadipani et al. 2021; Benzaquen 2021; Willis 2015). The general issues related to violence and the legitimacy of police action in the country are even more pronounced in Ceará. In fact, this northeastern coastal state with nearly 9 million inhabitants has the highest homicide rate in Brazil (FBSP 2021). In recent years, its capital Fortaleza has witnessed armed clashes between criminal groups dedicated to drug trafficking, which, in turn, has transformed it into the most violent state capital in Brazil (de Oliveira et al. 2019; Paiva et al. 2019).

By analyzing the effects of a reduction in policing on the time series of homicides in Ceará, this study aims to contribute to ongoing debates on violence and policing in Latin America, and particularly in Brazil (e.g., de Oliveira et al. 2019; Kopittke and Ramos 2021; Magaloni et al. 2020; Skogan and Riccio 2017). At the same time, by developing a quasi-experimental design, this study also contributes to the empirical analysis of the effects of de-policing on violent crimes (e.g., Cassell and Fowles 2018; Pyrooz et al. 2016; Shjarback et al. 2017; Yim et al. 2020). Indeed, while the magnitude of the contraction in policing examined by this study exceeded the forms of de-policing that are typically observed in contemporary advanced economies, the results of this research nonetheless underline the crucial role played by police presence in limiting serious violent crimes. Finally, this study is the first to analyze the impact on crime of a politically significant police strike in Brazil. As such, the study links with a body of research that investigates both the causes and the consequences of the frequent mutinies of police forces across Brazil (e.g., Benzaquen 2021; dos Santos Andrade 2021; Vieira Azevedo and Grazinoli Garrido 2019).

The paper is organized into five sections. The next section provides an overview of the latest developments in both the literature on de-policing and studies specifically focused on police strike actions. The second section presents the police strike in Ceará as a case study through which to investigate the impact of a radical reduction in policing. The third section argues in favor of the use

of quasi-experimental designs (i.e., ARIMA, STL+ETS, Difference-in-Differences) to estimate the impact of a reduction in policing on homicides, as well as describing the exploited data. The fourth section reports the results of the statistical analyses performed, which indicate an abnormal increase in violence in Ceará during the police strike action. The fifth section discusses the results in light of both prior studies on police deterrence and ongoing debates on police reform in Brazil.

Literature review

In the wake of notorious shootings of unarmed civilians by the police (e.g., Michael Brown in 2014 in Ferguson Missouri, Freddie Gray in 2015 in Baltimore), the causal relationship between a reduction in policing and an increase in criminal violence has received renewed empirical attention in the USA. One of the hypotheses under scrutiny contends that in response to both the increased public exposure and legal liability aroused by intolerance toward police brutalities, the police have adopted a less proactive enforcement approach and made fewer arrests, which, in turn, has led to an increase in criminal homicides. Several studies lend support to this hypothesis by showing a significant impact of de-policing on the occurrence of lethal violence. For instance, Morgan and Pally (2016) observed that shootings and murders in Baltimore rose in the two-month period immediately following Freddie Gray's murder. Rushin and Edwards (2017) evaluated if the introduction of more stringent police regulation was associated with an increase in crimes because it limited the effectiveness of police forces. Their findings indicate that the change in police regulation led to a significant increase in murders. Cassell and Fowles' (2018) results also evidence that de-policing impacts upon the occurrence of lethal violence; specifically, their analyses suggest that the increase in shootings and killings that occurred in Chicago in 2016 was likely caused by a reduction in arrests and searches. The thesis concerning the impact of de-policing on homicides has also received support from Gaston et al. (2019), whose analysis suggested that police illegitimacy, among other factors, contributed to a rise in homicides.

While several studies have identified a positive relation between different forms of de-policing and an increase in lethal violence in the USA from 2015 onwards, not all empirical analyses support this conclusion. For instance, the discontinuous growth model applied by Pyrooz et al. (2016) to criminal offence data spanning the period prior to and after the killing of Michael Brown, showed no evidence of a post-Ferguson increase in violent trends. Shjarback et al. (2017) examined the performances of police across 118 departments in Missouri from 2014 to 2015. Although the performed paired sample *t*-tests and OLS models identified reductions in the volume of police

activities, they also found a statistically significant increase in the “hit rate”, which suggests that police officers made better-quality stops. Consequently, the contraction in stops and arrests had no appreciable effect on total, violent, or property crime rates. Rosenfeld and Wallman (2019) estimated the simultaneous relationship between arrest and homicide rates between 2010 and 2015 in 53 large American cities and found no evidence that a decline in arrest rates impacted upon homicide rates. Finally, Yim et al. (2020) directly questioned whether the homicide rate in the USA in 2015 could be classified as abnormal. Relying on ARIMA prediction models, Yim et al. (2020) observed that the homicide rate in the USA between 2014 and 2015 increased above the 90% prediction interval, but not at more conservative intervals.

These studies form part of a broader body of literature that has used city—or state—level data to estimate the elasticity of crime with respect to the actual police workforce and its perception by the population. Notably, on analyzing the underlying reasons for a 52% decrease in the homicide rate in New York between 1992 and 1996, Fagan et al. (1998) identified the 25% increase in the number of police officers patrolling the city as a plausible explanation for the reduction in gun-related homicides. Conversely, by means of an *ad-hoc* survey distributed among the general population of 54 counties across the USA, Kleck and Barnes (2014) attempted to assess the accuracy of sanction risk perceptions. Ultimately, their analysis found no relationship between the number of police officers per capita and perceptions of the risk of arrest for carrying out a series of crimes, including homicide. Based on this finding, Kleck and Barnes (2014) asserted that increased police manpower does not have a deterrent effect per se, and, as such, has no impact upon homicide rates.

The impact of police presence and activities on the occurrence of violent crimes in society has not received equal academic attention outside the USA. Moreover, extant analyses on the effect of (possible) de-policing on the level of violence invariably concentrate on gradual modifications in the attitudes and practices of the police. Strong forms of de-policing due to a strike differ from de-policing due to the repercussion of incidents of police brutality in relevant manners. Changes in forms of policing induced by a change in the public perception of police activities are intended to strengthen police legitimacy and to reduce the scrutiny of police actions by citizens and the news media. To achieve this objective, officers may adopt behaviors that enable them to avoid situations that might require them to use force (Nix et al. 2018; Shjarback et al. 2017). Police strikes, instead, are tactics to acquire bargaining power in a labor dispute. They have the potential to cause civil unrest, and they often induce governments to claim the illegality of the strike and to appeal to the army to make up for the absence of the police (Benzaquen 2021). Therefore, rather than seeking

legitimacy by means of strike action, police sacrifice legitimacy to gain monetary or political benefits.

In this respect, there is a relative dearth of studies examining how more radical forms of de-policing impact upon the level of violence. In fact, with respect to advanced economies, the primary focus of most previous studies investigating police strikes has not been the effect of police absence on violence. For instance, the principal interests of scholars studying the police strike action that shocked Boston during the summer of 1919 were the evolution of labor laws and labor unions as well as the public perception of the strike action (Lyons 1947; Slater 1996). In this regard, it is reported that “[t]he first two days saw petty crime escalate into looting and violence” (Slater 1996, 16); nonetheless, the overall consideration paid to violent crimes was marginal. With respect to more recent strikes that occurred in eleven US cities during the late 1960s and 1970s, Pfuhl (1983) found no impact on appropriative crimes. Conversely, Summala et al. (1980) exploited a two-week police strike that occurred in Finland in 1976 to investigate how drivers reacted to an abrupt reduction in street patrolling.

Unsurprisingly, the attention paid to extensive police strike action is greater in contexts where these events are more frequent, such as Brazil, which has a long history of such events. Although police strikes are prohibited by the Brazilian Constitution, from 1997 to 2017 alone there were at least 715 cases in the country, 52 of which were mutinies by the Military Police (Tavares dos Santos et al. 2019).¹ Notwithstanding the fact that the level of violence in Brazil is particularly concerning, extant research on Brazilian police strikes has tended not to focus much on how they impact upon violent crimes, but rather on the historical and social factors that induced the turmoil (e.g., Benzaquen 2021), the balance between the legitimacy and legality of the police’s claims (e.g., dos Santos Andrade 2021; Vieira Azevedo and Grazinoli Garrido 2019), and on both the leaders of the protests and the content of their rhetoric (e.g., da Silva Neto and de Sá 2014). Similarly, the literature on police mutinies in other South American countries, such as, for example, Argentina or Peru, also does not focus on how they impact upon violence (e.g., Barreneche 2011; Quijano 2005).

¹ Technically, in the Brazilian legal system there is no such thing as strike action by military forces; rather, it is classified as ‘mutiny’ in the Constitution of Brazil (art. 142, IV) and article 149 of the Military Penal Code [Decree-Law No. 1001, of October 21, 1969. Military Criminal Code].

Current study

From the review of that extant literature, it emerges that findings pertaining to the degree to which contractions in police activities impact upon criminal violence are mixed with respect to the USA, and mostly lacking for more violent countries in other regions of the world. Indeed, analyses of more marked decreases in policing are everywhere rare due to the exceptional nature of such dynamics. Moreover, with a few exceptions, the principal focus of the limited studies that have concentrated on severe reductions in police presence has been the social, political, and legal context in which the police strike action occurred, rather than the impact that the contraction in policing had upon crime. There is even less research specifically focused on violence. Yet, the pervasive impact of homicide on individual lives, societies, and economies suggests that closer attention should be paid to most severe forms of violence (DeLisi et al. 2010). In light of this, questions remain concerning the actual impact that a large contraction in policing has upon violence. While the issue is of importance for all countries, it is even more pressing for those in which violence is more pervasive and the likelihood of de-policing is greater, which also happen to be the very countries for which empirical evidence is currently lacking.

This study exploits a mutiny by the Military Police in the Brazilian state of Ceará to investigate the impact of a marked reduction in police presence on the streets upon lethal violence. The basic idea is that, since the police mutiny was grounded in long-standing demands for a wage increase, its timing was exogenous with respect to the trend in homicides. In fact, although police functioning and societal violence mutually influence each other, the exceptional nature of the strike action suggests that its emergence is not dependent on the number of homicides. Indeed, both chronicles of the events and socio-political analyses of other strikes by the Brazilian police lend support to this hypothesis (e.g., Benzaquen 2021; dos Santos Andrade 2021; Melito 2020).

Since 5 December 2019, Ceará has been the site of protests by military police officers demanding a pay rise. On 13 February 2020, Governor Camilo Santana formalized a proposal to increase officers' salaries from BRL 3,200 to BRL 4,200 per month, with adjustments taking place until 2022 (Melito 2020). The police rejected this proposal and asked for a larger increase. On the night of 18 February, three police officers deflated the tires of a battalion's vehicles in the Metropolitan Region of Ceará in order to impede their use (Globo 2020). In the morning of 19

February, the Military Police actually began strike action (BBC 2020; Toledo 2020).² Over the course of only a few days, around 65% of the police officers patrolling the streets ceased to perform their activities, according to police associations. In response, the Brazilian president Bolsonaro allowed for the dispatch of up to 2,500 members of the army as well as a few hundred members of the national guard troops to Ceará between 21 and 28 February (Globo 2020). On 27 February, the governors of Maranhão, Rio de Janeiro, Bahia and Piauí agreed to send troops to Ceará to replace the troops that had been withdrawn by Bolsonaro on 28 February (Melito 2020). On the night of 1 March, the strike ended without the police receiving amnesty. In the morning of 2 March, the police were back on duty (Globo 2021).

The available information does not allow exact quantification of the level of participation in the strike and, hence, the exact level of variation in terms of police presence on the streets of Ceará. The Ceará Security Department did not confirm the figure provided by the police associations, which claimed that around 65% of military police officers took part in the strike, but it did not provide an alternative figure (Globo 2020). In 2021, the Military Police of Ceará comprised around 20,620 members (FBSP 2021). Therefore, if one accepts the estimate that 65% of the Military Police participated in the strike and includes in the estimate the 2,500 members of the army that were dispatched from the central government and other states, it is possible to estimate that the overall police presence diminished by around 50%. This estimate does not consider the 3,820 officers belonging to the Civil Police, whose tasks are primarily investigative and whose degree of participation in the strike was dubious.

According to routine activity theory (Cohen and Felson 1979), a strike reduces the presence of guardians and thus reduces individuals' perceptions of punishment risks (e.g., through lower police visibility), which, in turn, leads to an increase in violence. Usually, empirical support for the deterrent effect of the certainty of punishment relates almost exclusively to the certainty of apprehension (Nagin 2013). Aside from the direct effect of a reduced risk of apprehension for those who commit murder, a police strike may also foster violence through other indirect mechanisms. For instance, reduced guardianship may lead to an increase in appropriative crime and even looting, as

² The Military Police is a uniformed civilian police force that undertakes public safety and street policing functions. In fact, as per article 144 of the Brazilian Constitution, the Military Police is responsible for the ostensive policing and maintenance of public order, which makes it the principal crime fighting institution. The Civil Police are the other main police force in the country; the Civil Police are much less visible and numerous, and focus their activities on crime investigation. The Municipal Guards also contribute by both performing transit controls and regulating the use of public spaces.

was observed in Boston in 1919. In turn, the increase in appropriative crimes may trigger the use of violence both to commit appropriative crimes and to defend proprieties from them.

However, a significant increase in violence cannot be taken for granted. This is because of both findings on the lack of effect of previous police strike actions on crime (e.g., Pfuhl 1983) and, in the case considered here, the specificity of the Brazilian context, in which relationships between police forces and criminals are often strongly confrontational, unchecked police violence is common, and police action also triggers violence (Ahnen 2007; Magaloni et al. 2020; Willis 2015). For instance in São Paulo, “police—primarily Military Police—kill citizens daily, if not multiple times a day (1.6 on average in 2012); killing is often celebrated socially and within police hierarchies [...] the structure and incentives of police here do not aim to limit the number of people being killed—they incite it directly” (Willis 2015, 34). At the same time, it often happens that policemen are killed by Brazilian criminals (Ferreira 2019). In this regard, a police strike may reduce the violence committed and suffered by police officers. Moreover, governance-type criminal groups may mitigate the effects of the absence of the police by imposing security to gain further legitimacy in the areas where they are more deeply-rooted. Active in Ceará is the Primeiro Comando da Capital, a structured criminal organization which provides an alternative justice system in areas of Brazil (Reuter and Paoli 2020; Santos 2021). On the other hand, the existence of symbiotic relationships between police authorities and criminal groups may be manifest in the mediation by police of disputes that arise within criminal circles. Therefore, the absence of the police may give rise to an even more marked increase in criminal violence. Finally, even in the absence of a capable guardian, committing homicide exposes the murderer to considerable risks. First, violent crimes, especially when they occur within criminal circles, can provoke retaliation. Second, due to the gravity of the crime, investigators are unlikely to cease investigating a murder case once the strike is over. The risk of victimization and the risk of arrest are likely to lessen the impact of the strike on violence. The combination of all these factors requires the development of an analytical strategy which takes account of the fact that some of these factors favor the spread of violence, while others limit it.

Empirical methods

Analyzing the impact of police strike action on the level of homicides requires the identification or creation of a plausible counterfactual scenario in which police activity is unaltered. This counterfactual scenario can then be used as a control group against which to compare the actual frequency of homicides occurring during the strike. The simplest way to do this is to either select the

weeks prior to the strike or to focus on the same period in the previous year as a counterfactual scenario, and then compare the homicide counts during these periods with the homicide count during the police strike. However, these comparisons may lead to erroneous conclusions. Firstly, they fail to take into account random variation in the number of murders. Secondly, they do not consider long-term trends and seasonal variations, which affect year-to-year and within-year comparisons, respectively (Ashby 2020; Yim et al. 2020). To mitigate these potential sources of bias, the Autoregressive Integrated Moving Average (ARIMA) forecasting model is often used as the preferred approach with which to estimate an appropriate counterfactual scenario to investigate the time series of violent crimes—including homicides (e.g., Ashby 2020; Estévez-Soto 2021; Kim and Phillips 2021; Yim et al. 2020). In line with the increased use of this method, this study also produces a counterfactual scenario in which there is no police strike action. It does so by using an ARIMA model with seasonal components, which is often labelled ‘SARIMA’.³ The results are then corroborated by reconstructing a second virtual counterfactual scenario via the use of Exponential Smoothing with a seasonal and trend decomposition (STL+ETS) model, which is robust with respect to potential outliers and can handle any type of seasonality in the time series (Hyndman and Athanasopoulos 2021). Finally, the study conducts a difference-in-differences analysis which compares the trend in homicides registered in Ceará with the one observed in the Brazilian state of Alagoas, which did not experience police strikes.

ARIMA models

SARIMA is one of the conventional approaches of time series analysis. Like other time series forecast models, SARIMA is predicated on the notion that past observations of a phenomenon may provide good predictors of future observations (Box-Steffensmeier et al. 2014). Generally speaking, the key strength of the ARIMA approach is its performance in terms of forecasting. In fact, the values forecasted by ARIMA models tend to be more reliable than those of alternative forecasting models, especially with regard to short-term forecasts (Gujarati and Porter 2009). The inclusion of seasonal components enables consideration of the potentially significant seasonal fluctuation in crimes. For instance, previous studies have shown a higher occurrence of homicides during the summer months in Brazilian cities like São Paulo and Campinas (Ceccato 2005; Nogueira de Melo et al. 2018).

³ The Box and Tiao (1975) ‘univariate autoregressive moving-average (ARMA) analysis with the intervention approach’ provides a valid and efficient alternative to the ARIMA method. The principal difference between ARMA models and ARIMA models is the integral part of the latter (i.e., a measure of how many nonseasonal difference values are used to obtain stationarity). The preference for the ARIMA models derives from their wider adoption in recent homicide studies.

SARIMA models seek to capture the complexity and potential simultaneity of short-, medium- and long-term dependency processes by specifying the number of non-seasonal and seasonal autoregressive, integration, and moving average parameters (Box-Steffensmeier et al. 2014; Hyndman and Athanasopoulos 2021). SARIMA models assume the following form: $(p, d, q) \times (P, D, Q)_{[m]}$, where p indicates the non-seasonal Auto-Regressive (AR) order, d is the non-seasonal degree of differencing, q represents the non-seasonal Moving-Average (MA) order, and the uppercase notation refers to the equivalent components of the seasonal parts of the model. Finally, m indicates the seasonal period (i.e., number of observations per year), which in the current study corresponds to 52 weeks.

It follows that the use of SARIMA models entails selection of the number of periods to use in calculating the seasonal and non-seasonal auto-regressive (AR) and moving-average (MA) terms. The analysis reported in this study selected these terms automatically by using the algorithm defined by Hyndman and Khandakar (2008) and implemented in the R forecast package (Hyndman et al. 2021). Autocorrelations and trends were removed from the time series using the Box-Jenkins approach to fit time series data to a SARIMA statistical model (Box et al. 2015). Next, the algorithm enabled us to estimate multiple models with different values for the SARIMA terms and then to select the model with the best fit, which was measured through the corrected Akaike Information Criterion (AIC) (Cavanaugh 1997; Hyndman and Athanasopoulos 2021).

STL+ETS models

The results emerging from the SARIMA model were then corroborated by exploiting STL+ETS models. First, Seasonal and Trend decomposition using LOESS4 (STL) was used to decompose a time series into three components (i.e., trend, seasonal, residual) and to produce smooth estimates of them, as introduced by Cleveland et al. (1990). STL estimates are robust to outliers (i.e., they allow for a robust decomposition), so that occasional unusual observations in the time series do not affect the estimates of the trend-cycle and seasonal component (Hyndman and Athanasopoulos 2021). The counterfactual scenario for the period of the strike action was then produced by first subtracting the seasonality estimated using STL, and then by forecasting the de-seasonalized data via the use of an ETS algorithm for time series models. ETS computes a weighted average for all observations in the input time series as its prediction. In contrast to the use of constant weights that one sees in moving average methods, in ETS the weights are exponentially decreased over time.

⁴ LOESS stands for LOcally Estimated Scatterplot Smoothing.

Also with respect to the ETS, AIC can guide the selection of the best-fitting ETS model among different exponential smoothing methods, which vary according to the combinations of the trend and seasonal components (Hyndman and Athanasopoulos 2021). The model selected for the homicide series was an ETS(A,N,N). Therefore, the model components comprised additive errors, no trend, and no seasonality. The state space formulation of Holt's method is:

$$\begin{aligned}\text{Eq. 1) } y_t &= y_{t-1} + e_t \\ l_t &= l_{t-1} + \alpha e_t\end{aligned}$$

Which can be reformulated as a forecast and a smoothing equation:

$$\begin{aligned}\text{Eq. 2) } \hat{y}_{t|t-1} &= l_{t-1} \\ l_t &= \alpha y_{t-1} + (1 - \alpha)l_{t-1}\end{aligned}$$

where $\hat{y}_{t|t-1}$ is the forecast of y_t given the information of y_{t-1} ; while the second equation (i.e., smoothing equation) calculates the next level as the weighted average of the previous level and the previous observation.

Difference-in-Differences

The proposed ARIMA and STL+ETS models enable the identification of changes in homicide levels and their association with external events, but they cannot fully rule out the possibility that other unobserved confounding factors, besides seasonal variations, may have impacted upon homicides (see Shadish, Cook, and Campbell 2002). In other words, eventual variations in homicides might still be due to some general change that affected other areas of Brazil as well. In particular, in 2020, policies aimed at containing the spread of COVID-19 were implemented in most Brazilian states. Several research studies conducted around the world detected only minimal changes in homicide rates as a result of COVID-19 containment policies (e.g., Ashby 2020; Campedelli et al. 2020). Focusing on Brazil, no statistically significant variations in homicides in relation to COVID-19 containment policies was observed in São Paulo (Ribeiro-Junior et al. 2021). In Rio de Janeiro, homicides showed a marked decrease in May and June 2020 in comparison to the 2016-2020 average (Monteiro et al. 2021); however, available studies did not prove any causal relation between social distancing measures and the reduction in homicides observed in Rio de Janeiro.

Moreover, the timing of the spread of the coronavirus in Brazil suggests that social-distancing policies did not impact upon the routine of the inhabitants of Ceará until the end of the police strike. In fact, the first case of COVID-19 in Brazil was confirmed in the city of São Paulo on 26 February,

2020—one week after the strike started—with the first death on 17 March—two weeks after the end of the strike. Authorities confirmed the first case of COVID-19 in Ceará on 15 March—almost two weeks after the end of the strike. Starting from 16 March, there were social-distancing measures in Ceará but, as in most Brazilian states, there was no lockdown (Silva et al. 2020). In particular, in response to the spread of the virus, the Ceará government enacted social isolation regulations on 19 March, which was more than two weeks after the end of the police strike action (Lemos et al. 2020). Statistics on routing requests (<https://covid19.apple.com/mobility>) also confirm that social-distancing policies had no significant impact on mobility in Ceará until the latter half of March 2020.

Overall, the fact that Ceará authorities detected COVID-19 cases only after the strike ended suggests that the containment policies had no impact on homicides until the end of the strike. At the same time, the timing of the spread of the virus prevented controls from being formally included in the ARIMA and STL+ETS models. Indeed, data on mobility and on infections or deaths showed some variation only starting from the second half of March. Therefore, a difference-in-differences (DID) estimation approach was adopted to further assess the impact of the strike on the homicide level, thus corroborating the results obtained by means of forecasting approaches. The DID approach provided a control for the influence of COVID-19-related dynamics which were possibly not captured by control variables (e.g., mobility or infections data). In the same manner, the DID approach made it possible to control for the possibility that the results were due to some other general change that affected other Brazilian states.⁵

The analysis reported in this paper used DID to estimate the effect of the police strike (i.e., treatment) by comparing homicides (i.e., outcome) over time between Ceará (i.e., the treatment group) and the state of Alagoas (i.e., the control group). Alagoas has an estimated population of 3.3 million inhabitants; it is in the Northeast Region of Brazil and it is separated from Ceará by the state of Pernambuco. Like Ceará, also Alagoas is one of the most violent states in Brazil. Between 2015 and 2020, Alagoas' homicide rate fluctuated between 32.8 and 57.1 homicides per 100,000 inhabitants. In the same period in Ceará, the homicide rate ranged between 25.8 and 59.1 (FBSP 2021). As in Ceará, so in Alagoas, the first confirmed case of COVID-19 occurred after the end of the Ceará police strike, on 8 March 2020 (Baggio et al. 2021). Social distancing measures were then implemented in Alagoas with a schedule close to the one adopted by Ceará (see, Silva et al. 2020).

⁵ Synthetic controls, which combine data referring to multiple control units, would have been preferable to a DID comparison that used only one other state as counterfactual (see Abadie, Diamond, and Hainmueller 2010). However, the use of synthetic controls was ruled out due to the lack of suitable data (i.e., multiple multi-annual timeseries of weekly—or more frequent—homicide counts at the state—or sub-state—level).

Importantly, the police of Alagoas did not go on strike during or before the police strike that occurred in Ceará. All these factors suggested that Alagoas could act as a valid control for Ceará.

A Poisson model was used to define the DID approach, because the outcomes of the models (i.e., number of homicides) were counts. Therefore, the effect of the police strike in Ceará was estimated using the following regression model:

$$\begin{aligned} \text{Eq. 3) } E(H_{it}) &= e^{\mu_{it}} \\ \mu_{it} &= \alpha + \beta_1 S_{it} + \beta_2 T1_t + \beta_3 \gamma_i + u_{it} \end{aligned}$$

where H_{it} is the number of homicides in state i —either Ceará or Alagoas—in week t ; $T1_t$ is a control for the period of the strike (i.e., $T1_t$); γ_i is a fixed effect for states (i.e., treatment and control groups). S_{it} is the treatment dummy variable representing the fact that the strike was ongoing in Ceará. Therefore, β_1 is the parameter of interest which captures the relation between the strike and homicides. S_{it} is given by the interaction of the variable for states and for time-periods. Finally, u_{it} are time-varying unobservables that are mean independent of everything else.

A second set of models differentiated among the periods before the beginning of the strike, during the strike, and after the strike (i.e., $T2_t$). Contextually, a variable representing the inertia of violence in the period after the strike was added to the model (i.e., I_{it}); this variable was equal to 1 if i was equal to Ceará and simultaneously t corresponded to the weeks after the end of the strike. Finally, the models included a weekly fixed effect (i.e., δ_t). The use of the DID fixed effects specification made it possible to control for unobserved heterogeneities between states and over time. In formula:

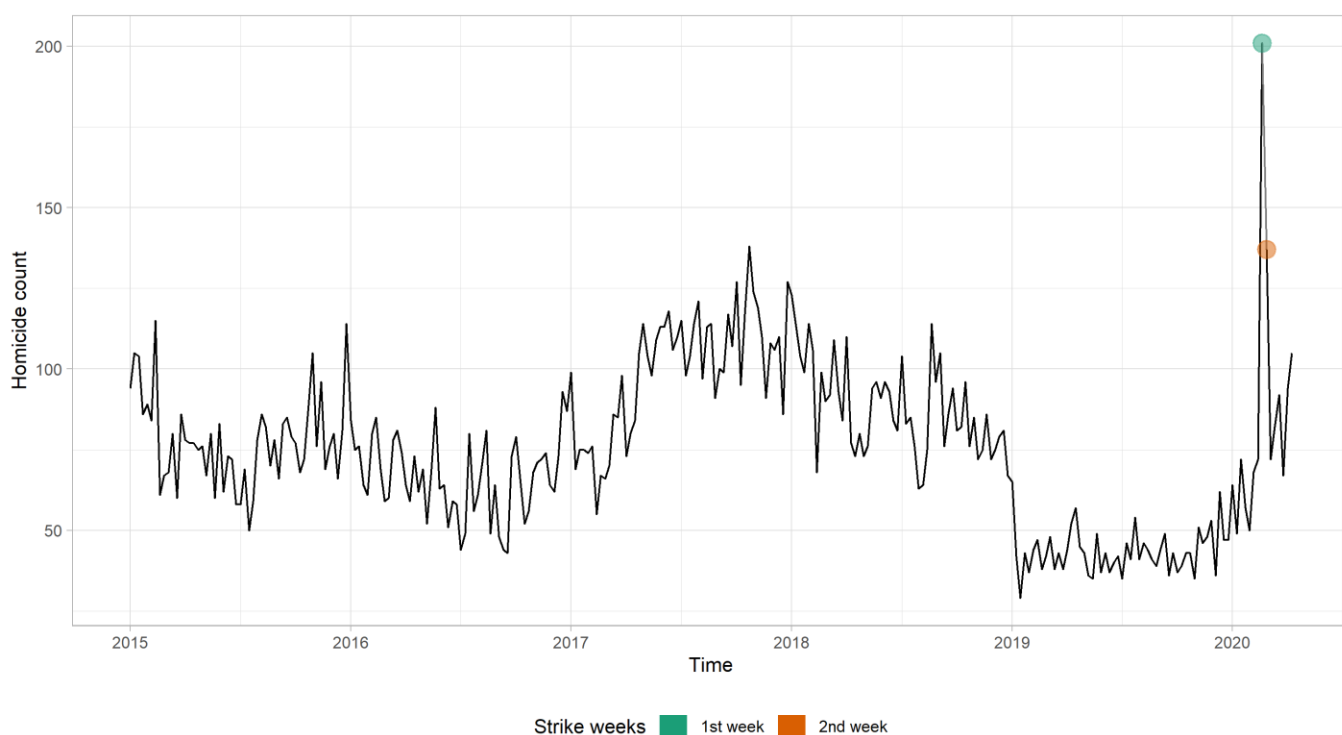
$$\begin{aligned} \text{Eq. 4) } E(H_{it}) &= e^{\mu_{it}} \\ \mu_{it} &= \alpha + \beta_1 S_{it} + \beta_4 I_{it} + \beta_5 T2_t + \beta_3 \gamma_i + \beta_6 \delta_t + u_{it} \end{aligned}$$

Data

To both train the ARIMA and STL+ETS models and produce the forecasts, daily homicide counts registered in Ceará (20,640 cases in total) were aggregated weekly. The aggregation of daily data into weeks mitigated oscillations between successive observations of the variable of interest, thus reducing both the error in the forecasts and potential biases stemming from the imprecise reporting of the date of a homicide. Moreover, it removed the weekly patterns in the data, thus leaving only longer temporal dependencies in the data that the exploited models could more

effectively account for. Time series data on homicides from 1 January 2015 to 31 March 2020 (Fig. 1) were retrieved from the website of the Secretariat of Public Security and Social Defense of the Government of the State of Ceará, which provides openly available daily data on intentional lethal violence (www.sspds.ce.gov.br). Starting in 2016, violent confrontations between factions of drug traffickers for access to the lucrative transatlantic cocaine shipping routes plagued the North and North-East of Brazil, causing an increase in homicides. Following an armistice between rival factions, a strong reduction in homicides was recorded in 2018 and especially in 2019 (Santiago et al. 2021).

Fig. 1. Time series of the weekly homicide count in Ceará from 1 Jan. 2015 to 31 Mar. 2020



Note: The graph represents the time series of weekly homicides in Ceará from 1 January 2015 to 31 March 2020. The observation corresponding to the first week of the strike is highlighted in green; the observation corresponding to the second week of the strike is highlighted in orange.

The models were trained on the period before the strike from 1 January 2015 to 18 February 2020 (week 7 of 2020). The forecasts emerging in the counterfactual scenario were first compared with the homicides that were actually recorded in the two-week period from 19 February 2020 (week 8 of 2020) to 3 March 2020 (week 9 of 2020), which constitutes the core period of the strike.⁶

⁶ Alternatively, it would have been possible to produce a counterfactual scenario starting on 18 February, the day of the first episodes of insubordination. However, this would have required assigning the homicides recorded on 31 December

Finally, comparisons were made between the forecasts and the actual data referring to the four weeks immediately following the strike as an additional check of its impact; these were the weeks beginning on 4 March and ending on 31 March 2020 (from week 10 to week 13 of 2020) (Table 1).

Table 1. Summary statistics of the time series used (SARIMA and STL+ETS models)

	Period			
	Pre-strike	Police strike	Post-strike	Entire
Function	Model training	Event observation	Additional comparisons	Graphic representations
Dates	Jan.01.2015- Feb.18.2020	Feb.19.2020- Mar.03.2020	Mar.04.2020- Mar.31.2020	Jan.01.2015- Mar.31.2020
Weeks	1-267	268-269	270-273	1-273
Obs.	267	2	4	273
Mean	74.7	169.0	78.3	75.4
Std. Dev.	23.4	45.3	11.1	24.7
Skewness	0.2	0.0	0.3	0.6
Kurtosis	2.3	1.0	1.6	4.4
Range	29-138	137-201	67-92	29-201

Note: the daily observations were grouped into 52 weekly observations for each year. Given that there are 365 days in the year (366 in 2016 and in 2020, which were leap years with a twenty-nine-day-long February), an additional day was imputed to the 52nd week of each year (two days in the case of both 2016 and 2020).

To perform the DID analysis, time series data on homicides in Alagoas from 1 July 2019 to 31 March 2020 were retrieved from the website of the Secretariat of Public Security and Social Defense of the Government of the State of Alagoas (<http://seguranca.al.gov.br/>) (Table 2). Homicide counts were log transformed to ensure that Ceará and Alagoas had parallel trends in homicides in the pre-strike period. The DID estimator requires, in fact, that in the absence of the treatment, the average outcomes for treated units and controls would have followed parallel paths over time (Abadie 2005). Homicides were observed in the thirty-three weeks before the strike, from mid-2019 onwards, while the six weeks starting on 19 February 2020 were used as the post-treatment period in order to monitor the same period as with SARIMA and STL+ETS. Both the graphical test and a statistical placebo analysis suggested the absence of a violation of the parallel-trends assumption (Fig. 2). In the placebo test, treatment was reassigned 16 weeks prior to the strike, and then the DID model (Equation 4) was performed for all pre-treatment data. If the treatment coefficient had explanatory power, we would have concluded that Ceará was already seeing changes in its homicide trend relative to Alagoas without a police strike, violating the parallel trends assumption (see Lechner

of each year to the first week of the following year. The results of the two options are consistent, although the specifications of the preferred forecasting models are slightly different. The option with years and weeks starting on January 1 of each year was preferred for presenting the results because it more precisely captured the moment at which the police presence decreased in the streets and because it did not assign homicides registered in a year to the previous one.

2011). The analysis performed indicated that the treatment coefficient was not statistically significant ($p = 0.968$), thus suggesting that the parallel lines assumption was probably not violated.

Table 2. Summary statistics of the time series used (Difference-in-Differences models)

	Ceará			Alagoas		
Function	Treatment			Control		
Period	Pre-strike	Mar.04.2020	Post-strike	Pre-strike	Mar.04.2020	Post-strike
Dates	Jul.01.2019 Feb.18.2020	Feb.19.2020 Mar.03.2020	Feb.19.2020 Mar.31.2020	Jul.01.2019 Feb.18.2020	Feb.19.2020 Mar.03.2020	Feb.19.2020 Mar.31.2020
Obs.	33	2	4	33	2	4
Mean	47.8	169.0	78.3	22.6	36.5	24.3
Std. Dev.	10.2	45.3	11.1	5.3	3.5	6.1
Skewness	1.0	0.0	0.3	0.4	0.0	-0.0
Kurtosis	3.2	1.0	1.6	3.9	1.0	1.1
Range	35-72	137-201	67-92	12-38	34-39	18-30

Fig. 2. Time series of the weekly homicide counts (log. of) in Ceará and Alagoas from Jul. 2019 to Mar. 2020



Note: The graph represents the time series of the homicide counts (log. of) in Ceará (i.e., treatment) and Alagoas (i.e., control) from July 2019 to the end of March 2020, together with their trends before the beginning of the strike (i.e., S.B.) and their 99% confidence intervals.

Potential sources of bias and limitations

While both ARIMA and STL+ETS are powerful instruments for generating forecasts, and difference-in-differences analysis is a valid approach with which to deal with the potential impact of COVID-19-containment policies, the proposed methodology was not without its limitations. Firstly, homicide forecasts may be characterized by more errors than other crimes as a consequence of their relative scarcity, not to mention that these forecasts are further complicated by the fact that their fluctuations may be influenced by different layers of seasonality (Ashby 2020; Yim et al. 2020). To mitigate this factor, daily data were aggregated into weekly data. However, producing weekly forecasts introduced a downward bias in the estimate of the effect of the strike action—irrespective of its direction—because the treatment groups of 14 days included only 12 actual days of strike.⁷ On the other hand, homicides are less under-reported and less under-recorded in comparison to other crimes. While accounting for under-reporting in crime statistics is always important, it is even more so in the specific case under analysis here, because the disruption to police routines caused by the strike may have affected reporting behavior which, in turn, may have caused a downward bias of the estimate of the impact on homicides of the police presence on the streets. In this respect, the gravity of the crime considered means that it is relatively uncommon for a homicide not to be reported or discovered by law enforcement agencies (Aziani 2020). Moreover, also in the Brazilian context, where homicides are more frequent than in most other countries, the underreporting of homicides is marginal (Costa et al. 2018). Finally, the available information did not allow for exact quantification of participation in the strike and, hence, of the precise variation of police presence on the streets of Ceará. The high level of uncertainty in this estimate reverberated on the estimate of the elasticity of crime to policing, which should be considered tentative.

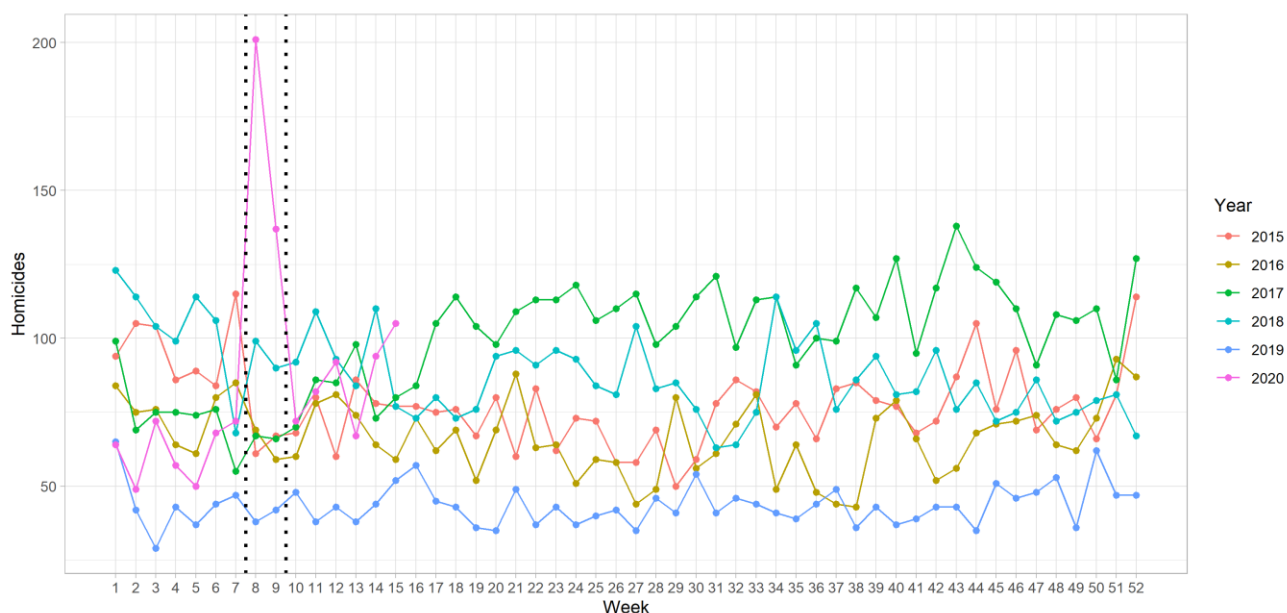
Results

The exploratory analyses of homicide counts suggested that lethal violence increased markedly once the police strike action began. February 2020 was the most violent month on record since 2013, when the Ceará Secretariat of Public Security began to adopt its current methodology for counting homicides. In February 2020, the authorities recorded 459 homicides: 294 more than in February 2019 (+178.2%) and 194 more than in January 2020 (+83.6%). The peak in lethal violence is even more evident when one concentrates on the two-week period in which the strike took place. In the week preceding the strike, 72 episodes of lethal violence were recorded in Ceará. In the periods from

⁷ On both 2 and 3 March 2020, which were considered as treatment days despite their being the first and second days after the strike, there were nine homicides recorded, which was less than on any other day during the strike.

19 to 25 February and 26 February to 3 March, recorded homicides amounted to 201 and 137 respectively, thus corresponding to a 179.2% and a 90.3% increase in comparison to the week before the strike, when there were 72 recorded homicides. Recorded in the week after the strike were 72 episodes of lethal violence, which corresponded to a 90.3% decrease compared to the second week of the strike (Fig. 3). A percent change analysis suggested that the police strike was associated with an increase in the frequencies of episodes of lethal violence. Nonetheless, this exploratory analysis did not address the complex time series patterns present in the data, which required the adoption of more sophisticated modeling approaches, whose results are presented in the following paragraphs.

Fig. 3. Weekly homicide counts from Feb. 19 and Mar. 03, 2020, compared with the weekly counts observed between Jan. 1, 2015 and Mar. 31, 2020



Note: The graph compares the homicides recorded in Ceará in the two weeks of the police strike (i.e., fuchsia observations within the vertical dotted lines) with the weekly homicide counts recorded from 1 January 2015 to 31 March 2020.

Forecasting (ARIMA and STL+ETS models)

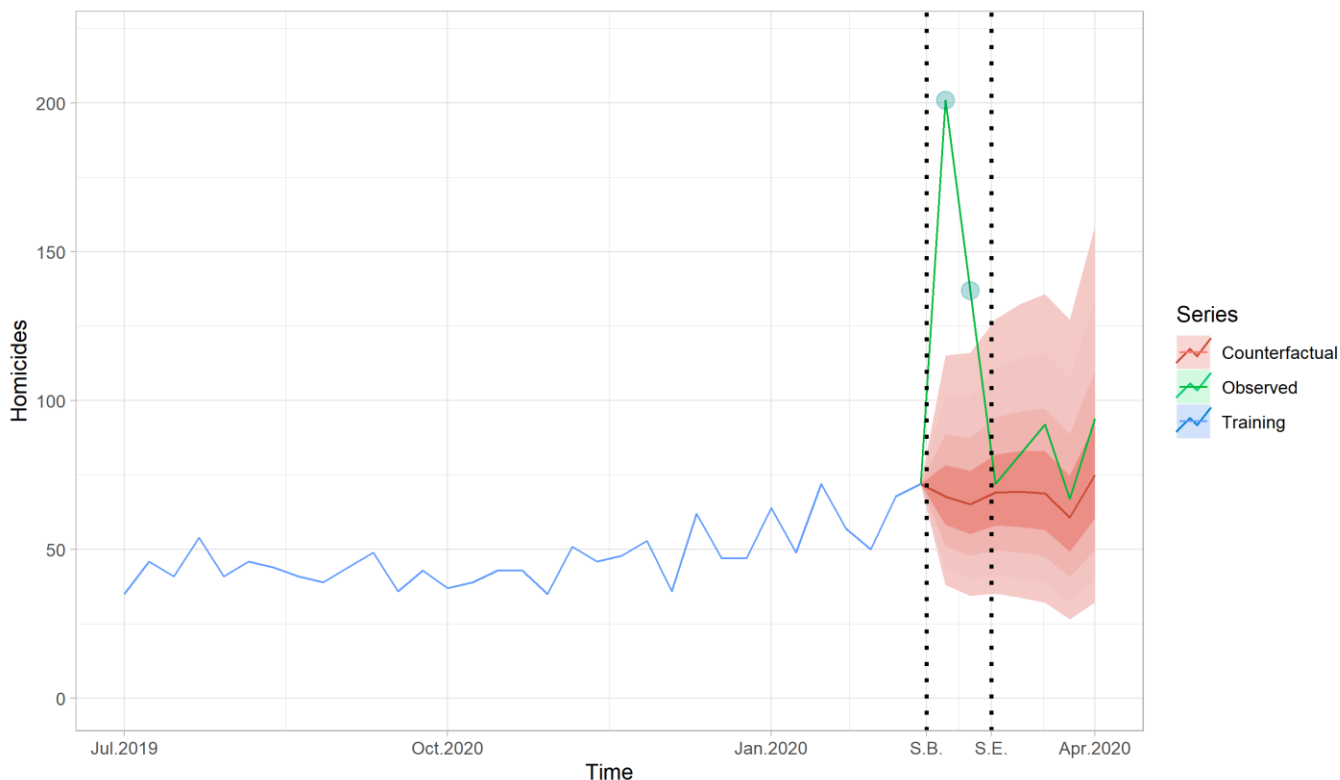
The out-of-sample accuracy measures for the period during the strike provided an estimate of the effect of the strike more robust than the comparison between homicide counts. The mean error for homicides was positive (ME =102.54), which means that the observed values of homicides during the two-week strike were consistently larger than those expected on the basis of the modelling

of the pre-strike period (Table 3).⁸ The significance of the increase was also confirmed by comparing the observed homicides with the virtual counterfactual produced on the basis of ARIMA forecasts (Fig. 4). The observations corresponding to the strike periods were above the 99% prediction interval of the forecast model. 201 episodes of lethal violence were registered during the first week of the strike, almost three times more than the 67.76 forecasted by the model [99% Prediction Interval: 38.03 - 115.15], which corresponds to an estimated increase in homicides equal to +196.64%. In the second week of the strike, official statistics reported 137 episodes of lethal violence; the model forecasted a counterfactual of 65.15 [99% Prediction Interval: 34.53 - 116.15]. Therefore, with respect to the week covering the second part of the strike, registered homicides were more than double the number expected (110.28% higher). After the end of the strike, the observed number of homicides remained within the prediction intervals of the forecast. In the 10th and 11th weeks of 2020, before the Ceará government introduced any COVID-19-related social distancing measure, actual homicides were 72 and 89, whereas the model predicted 69.12 [99% Prediction Interval: 35.18 - 127.40] and 69.39 homicides [99% Prediction Interval: 33.84 - 132.43], respectively. In the final two weeks of the forecast, spanning from 18 to 31 March, the observed homicides were also higher than the predicted values, but the observed discrepancies were not statistically significant. The forecasts based on the use of the STL+ETS model were slightly lower than the one emerging from the ARIMA model.⁹ As such, they confirmed the main result of the analysis: the number of homicides during the strike was significantly higher than the forecast at any common predicting interval (i.e., between +196.64% and +251.62% during the first week, and between +110.28% and +144.00% during the second week) (Fig. 5).

Fig. 4. Weekly homicide counts from Apr. 2019 to Apr. 2020 compared to counterfactual estimates based on SARIMA models estimated using data from Jan. 01, 2015 to Feb. 18, 2020

⁸ The minimization of the corrected Akaike Information Criterion led to the selection of the model ARIMA(4,1,0)(1,1,0) to fit the time series of homicides that occurred between 1 January 2015 and 18 February 2020. The analysis of the goodness of fit of this model indicated that the chosen model reasonably accounted for autocorrelation and can thus be used as an adequate model for forecasting lethal violence over time. Annex 1 presents the goodness of fit analysis for the ARIMA model and its results.

⁹ Annex 2 presents the specifications and the results of the STL+ETS analysis.



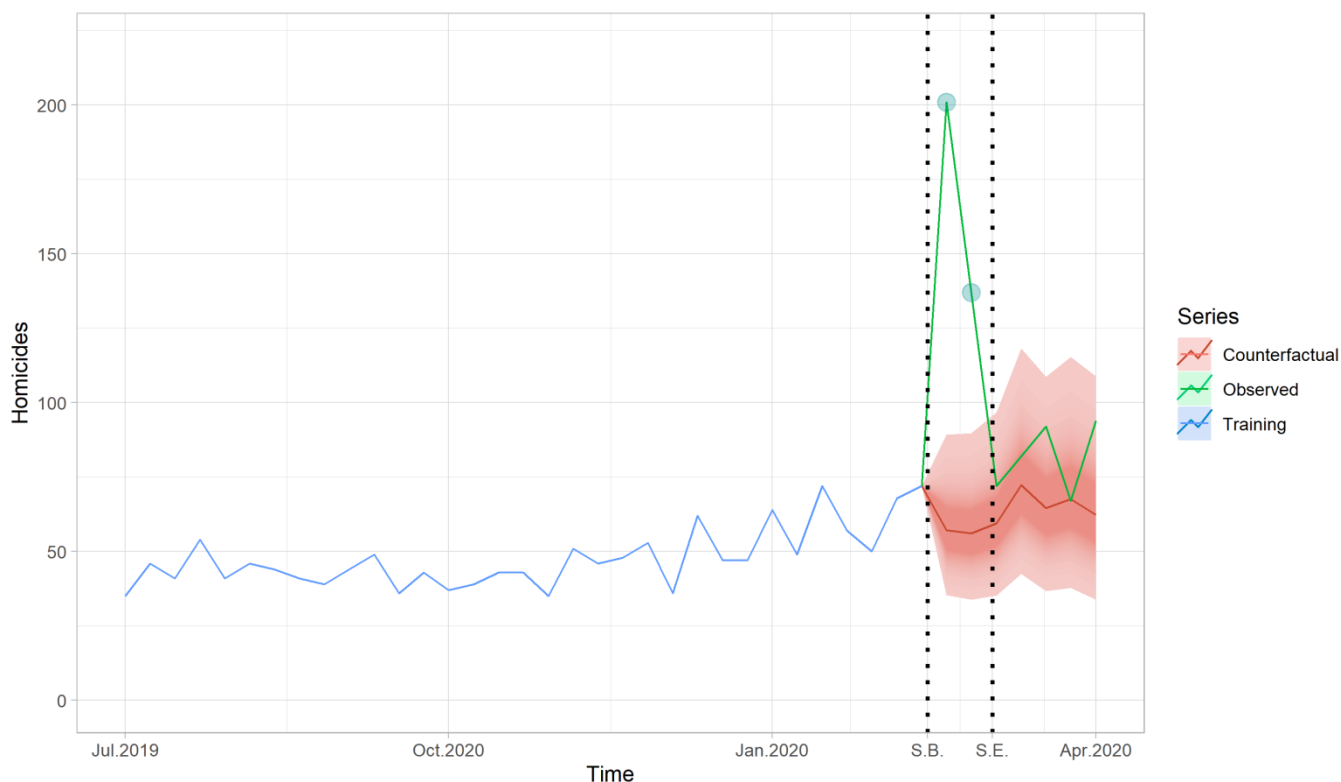
Note: Four prediction intervals including 51, 90, 95 and 99% are represented with shades of red in order. The 51% prediction interval is displayed with the darkest red band, while the 99% band is in the lightest shade of red. The bands were computed from estimated ARIMA(4,1,0)(1, 1, 0) model on the homicide counts in the 8th and 9th weeks of 2020 (period within the vertical dotted line) and were based on prior actual observations since the 1st week of January 2015.

Table 3. Accuracy measures of the preferred model

	<u>Specification</u>	<u>Pre-Strike</u>			<u>During the Strike</u>		
		ME	MAPE	MASE	ME	MAPE	MASE
Lethal violence	ARIMA(4,1,0)(1,1,0) [52]	0.04	13.64	0.32	102.54	59.37	3.44

Note: ME is the Mean forecast Error; MAPE is the Mean Absolute Percentage Error; MASE is the Mean Absolute Scaled Error.

Fig. 5. Weekly counts of homicides from Apr. 2019 to Apr. 2020 compared to counterfactual estimates based on the STL+ETS(A,N,N) model estimated using data from Jan. 1, 2015 to Feb. 18, 2020



Note: A continuum of prediction intervals are represented with shades of red in order. The 51% prediction interval is displayed with the darkest shade of red, while the 99% band is in the lightest shade of red. The prediction intervals were computed from the STL+ETS(A,N,N) model estimated on the count of homicides in the 8th and 9th weeks of 2020 (period within the vertical dotted line) and based on prior actual observations since the 1st week of January 2015.

Difference-in-differences

A first difference-in-differences analysis, which considered the period during which the police strike was ongoing and the periods in which it was not (i.e., Equation 3), indicated that the strike was associated with almost a doubling (91.0% increase) of homicides in Ceará (Model 1 in Table 4). The association between the strike and the increase in homicides is significant at 99% level. Models 2 to 4 distinguish the effect of the strike in the period in which it was ongoing (S_{it}) from the effect of the strike in the four weeks after it ended (I_{it}), while controlling for the effects of the periods during and after the strike ($T2_t$ in Model 2 and 3) and for time-dependent factors (δ_t in Models 3 and 4). In these other specifications, during the police strike, the increase in homicides ranges between +76.1% (Model 2 and 3) and +104.5% (Model 4). The difference-in-differences analysis indicates that the Ceará police strike was associated with a higher number of homicides also in the four weeks following the end of the strike (Model 2 to 4). The association between the strike and the number of homicides in the aftermath of the strike is statistically significant at 99% confidence level in all three econometric specifications. The size of the increase in the post-strike period ranges between +24.9% and +43.3% homicides per week, depending on the model specifications.

Table 4. Difference-in-differences models

	Dependent variable: Homicide count (log. of)			
	(M1) Strike & non-strike	(2) Pre-During-Post	(3) Pre-During-Post with temporal controls	(4) Pre-During-Post with week fixed effect
DID				
Police strike (S_{it})	0.910*** (0.159)	0.761*** (0.154)	0.761*** (0.156)	1.045*** (0.149)
Violence inertia (I_{it})		0.433*** (0.138)	0.433*** (0.134)	0.249*** (0.084)
Time controls				
Strike period ($T1_t$)	0.336*** (0.086)			
During strike ($T2_t$)		0.504*** (0.064)	0.271*** (0.073)	
After strike ($T2_t$)		0.073 (0.119)	-0.200 (0.124)	
Fixed effects				
State (Ceará) (γ_i)	0.793*** (0.051)	0.756*** (0.054)	0.756*** (0.044)	0.760*** (0.044)
Week (δ_t)			0.013*** (0.002)	0.013*** (0.002)
Constant (α)	3.073*** (0.040)	3.091*** (0.041)	-38.272*** (7.284)	-35.875*** (7.408)
Observations	78	78	78	78
Adjusted R ²	0.810	0.826	0.887	0.866
Residual Std. Error	0.230 (df=72)	0.220 (df=72)	0.185 (df=71)	0.193 (df=73)
F Statistic	110.31*** (df=3; 74)	73.95*** (df=5; 72)	92.46*** (df=6; 71)	124.88*** (df=4; 73)

Note: *p<0.1; **p<0.05; ***p<0.01. Robust Standard Errors are provided in parentheses.

Discussion and conclusions

Evaluating the impact of police presence on crime constitutes a challenge because crime levels also influence the level of police presence. Police strike actions motivated by exogenous factors, such as wage claims for example, furnish a rare opportunity to empirically assess the extent to which the police presence deters crime. The results of the analyses indicate that the number of homicides in Ceará was abnormally high during the two weeks in which a reduction in street patrolling occurred: the estimated increases in homicides ranged between +76.1% and +251.6% depending on the estimation approach and the week considered. Although the available information does not make it possible to precisely evaluate the magnitude of the actual reduction in policing, existing accounts of the strike are nevertheless consistent in terms of describing it as large (e.g., Globo 2020; Melito 2020). Assuming a constant 50% contraction in police presence on the streets during the strike, the estimated elasticity of homicides to police presence tentatively ranges between -1.5 and -5.0,

depending on the different estimates of the increase in homicides.¹⁰ If the participation of police officers in the strike was actually lower, the elasticity would be even stronger. As such, it is safe to assume that the reduction in policing caused a large increase in the occurrence of lethal violence. This finding corroborates a large body of research which identifies the perceived risk of apprehension by the police as fundamental factor of deterrence, and that the absolute deterrent effect of policing is large (see Dau et al. 2021; Naginjacob et al. 2015).

Unlike most previous research, the results of this study derive from a marked reduction of policing in an area of a developing country characterized by pre-existing and singularly high levels of violence. They do not emerge from the analysis of marginal changes in the number of police officers observed in advanced economies. Police strikes differ from routine or strategic variations in police strength (Kleck and Barnes 2014; Nagin 2013). In particular, no strategies were planned in advance to mitigate the impact of the reduction in policing; rather, the response to the strike consisted of sending replacement troops and enjoining the population to exercise prudence. Police strikes differ also from less abrupt forms of de-policing, because police officers who disengage from active police work to avoid external scrutiny may still deter crimes by means of their mere presence; in police strikes, like the one analyzed here, this cannot occur. Consequently, it is not possible to assume that equally large increases in homicides would be observed in other contexts where the police presence decreases less abruptly. In fact, the obtained estimates of the elasticity of homicides to police presence (i.e., between -1.5 and -5.0) are larger than most of those obtained for medium-to-large US cities (see Chalfin and McCrary 2018). However, it is not the case that the findings reported here are only valid for the specific region and period under examination. Whilst abrupt episodes of de-policing and widespread violence are extremely rare in the Global North, this is not the case in Brazil or other parts of Latin America. It thus follows that the implications of this analysis may apply to other contexts characterized by the presence of criminal groups, high levels of lethal violence, and the politicization of the police.

All the estimates also showed that, in the month following the strike, actual homicides in Ceará continued to be more frequent than they were in the counterfactual scenarios. ARIMA and STL+ETS models indicated that this difference was not statistically significant, while difference-in-differences analyses suggested that the difference was significant. The discrepancies in the statistical

¹⁰ *Elasticity of homicides to police presence* = $\frac{\% \text{ Change in Homicides}}{\% \text{ Change in Police Presence}}$. Assuming a 50% contraction in police presence and taking the lowest estimate of homicide increase (i.e., +76.1%), the elasticity is about -1.5. Assuming a 50% contraction in police presence and taking the lowest estimate of homicide increase (i.e., +251.6%), the elasticity is about -5.0.

significance of the effect of ‘violence inertia’ may have been due to a general decrease in homicides caused by the spread of COVID-19 in Brazil in the weeks following the end of the strike, which the difference-in-differences method captures more effectively than the forecasting strategies do. If homicides did not return to their original level in the aftermath of the strike, this protraction of violence may have been due to the onset of spirals of violence and revenge in criminal circles (Jacobs and Wright 2006). Likewise, it could also be that the police officers, who did not obtain the pay rises that they demanded, purposefully limited their activities after they returned to work. In turn, these forms of de-policing may have decreased the deterrent effect of police presence on the streets.

Police mutinies such as that the one analyzed in this study touch upon the broader problem of police legitimacy and fairness in Brazil, which encompasses extreme forms of police corruption, brutality, and discrimination (Alcadipani et al. 2021; Willis 2015). At the same time, the Brazilian police are often insufficiently trained, receive low wages, have poor working conditions, and experience high victimization rates (Ferreira 2019; Skogan and Riccio 2017). Evidently, there are no simple and circumscribed solutions to such complex and multilayered problems, which range from budget constraints to racism within society at large. Nonetheless, on looking at the tremendous costs of the numerous police mutinies, one can conclude that it would be a profitable area of investment for Brazilian institutions to increase both the level of internal accountability and external oversight over the police. How to achieve these objectives is, however, far from obvious.

Finally, the findings indicate that criminal groups were either not fully effective in enforcing peace in the absence of the police or that they exploited the reduction in surveillance to engage in violent behavior. Criminal gangs and organized criminal groups are able to provide security governance and de-facto policing within marginalized communities in areas of Rio de Janeiro or São Paulo (Reuter and Paoli 2020; Santos 2021). In consideration of this, further studies could seek to investigate if and how, in these other contexts, organized criminal groups can provide security governance in response to de-policing. More generally, analyzing the effects of policing on crime in Brazil and in the Global South remains an important avenue for future research to explore, because several questions remain unanswered. Changes in the geographic distribution of crimes (e.g., from less to more affluent neighborhoods), as well as in the socio-demographic characteristics of the victims during and in the aftermath of reductions in policing, also warrant further investigation, insofar as the results of these analyses might provide tangible evidence of the influence of police practices on safety inequality, which is one of the most pressing issues in Brazilian society.

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Annexes

Annex 1. Goodness of fit analysis for the ARIMA model

The analysis of the residual statistics referring to the model ARIMA(4,1,0)(1,1,0) confirmed the adequacy of the selected model and aligned with the results of the Dickey-Fuller tests (Dickey-Fuller = -1.820, p -value = 0.652), which indicated that it was not possible to reject the null hypothesis that the homicide timeseries was non-stationary and that the first-order difference was needed (Fig. A1.1). The autocorrelation function (ACF) plot indicated that the lagged observations did not show any significant spike, thus suggesting that there was no significant autocorrelation left, and that the mean of the return process was not significantly different from zero. The implementation of the test statistic $\lambda_{2,t}$ proposed by Chang et al. (1988) identified neither innovational outliers (IO) nor additive outliers (AO) in the fitted model. A formal check of the autocorrelations of the residuals also suggested that the errors were white noise. Indeed, the p -value of Ljung-Box test for the residuals was higher than 0.05 (Ljung-Box Q at lag 53 = 44.21, p -value = .630), which means that we failed to reject the null hypothesis that there was no autocorrelation between the errors and the model did not show a lack of fit (Ljung and Box 1978). Moreover, the statistical significance of the parameters of the model confirmed its good fit (Table A1.1). Finally, both the mean absolute percentage error (MAPE = 13.64) and the mean forecast error (ME = 0.04) of the fitted model suggested that the ARIMA(4,1,0)(1,1,0) model reasonably captured the complexity of the time series prior to the strike. The mean absolute scaled error (MASE) of the model was smaller than 1, which means that the chosen model had a smaller error than a naïve model in which homicide frequency is forecast as being the same as it was in the previous week.

Fig. A1.1. Residual fit statistics for ARIMA(4,1,0)(1,1,0) model on weekly homicide counts from Jan. 01, 2015 to Feb. 18, 2020 (training)

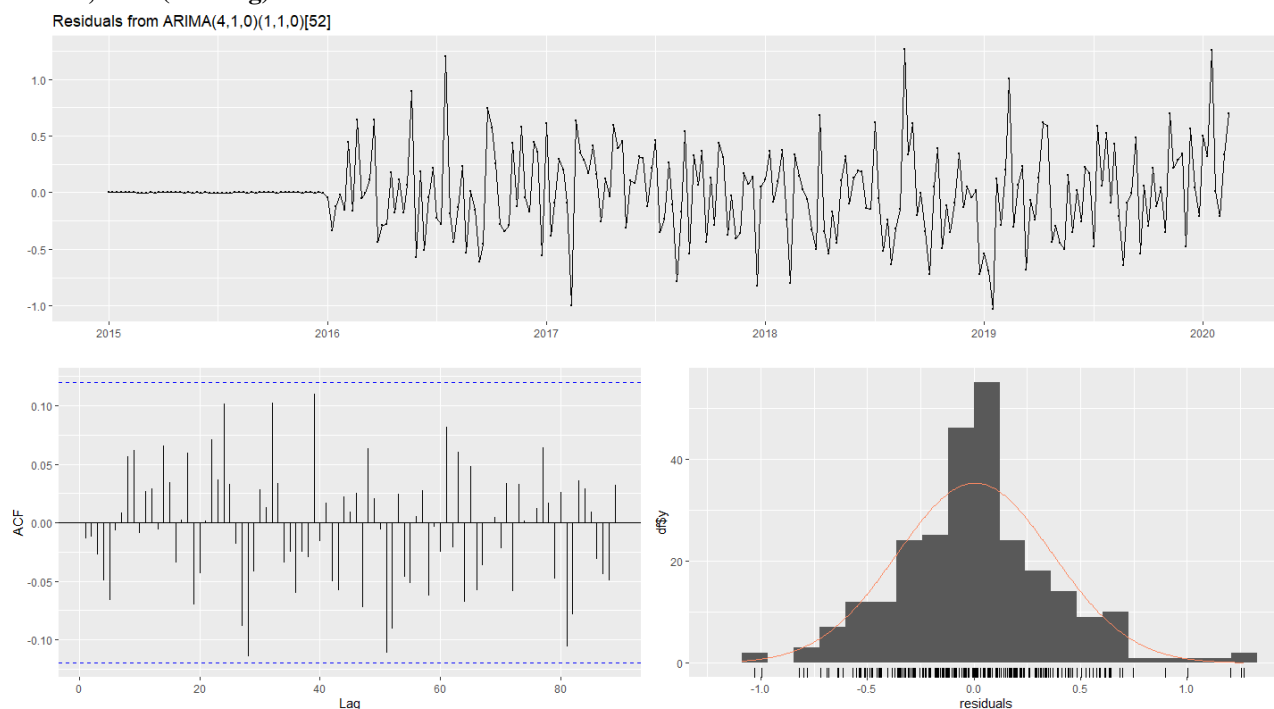


Table A1.1. Statistical significance of the parameters of the ARIMA (4,1,0)(1,1,0) model

Parameter	Estimate	Std. Error	z value	Pr(> z)
ar1	-0.57	0.07	-8.35	0.00***
ar2	-0.34	0.08	-4.37	0.00***
ar3	-0.21	0.08	-2.65	0.01**
ar4	-0.13	0.07	-1.89	0.06 [†]
sar1	-0.51	0.06	-7.94	0.00***

Note: Training from Jan. 1, 2015 to Feb. 18, 2020. ***, **, *, and [†] indicate statistical significance at .001, .01, .05, and .1, respectively.

Annex 2. Results of the STL+ETS forecasting

As in the case of the ARIMA model, the residual analysis of the ETS showed that the model combining STL and ETS captured the underlying dynamics with well-behaved residuals resembling white noise and close to normal distribution (Fig. A2.1). Consequently, it is possible to produce a counterfactual scenario for the two weeks of strike action. The 201 homicides registered in the first week of the strike were 251.62% higher than expected on the basis of the STL+ETS model [99% Prediction Interval: 35.41 – 89.30]. In the 9th week of 2020, 137 homicides were registered in Ceará, whereas there were predicted to be 56.15 [99% Prediction Interval: 33.85 – 89.78] in the virtual counterfactual scenario based on the use of STL+ETS. This means that the actual homicides were 144.00% higher than forecasted. In the two-week period following the strike, homicide counts remained higher than forecasted, but the difference between the counterfactual scenario and the

observed time series was not statistically significant at any conventional prediction interval. on combining the estimates emerging from the use of the two classes of models, the estimated increase in homicides during the first week of the strike ranges between 196.64% and 251.62% and between 110.28% and 144.00% during the second week.

Fig. A2.1. Residual fit statistics for STL+ETS(A, N, N) model on weekly homicide count Jan. 1, 2015 to Feb. 18, 2020

