# How the COVID-19 pandemic hit crime in Barcelona: Analysis of variation in crime trends

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## Abstract
## Objectives:

To compare the observed and forecasted crime trends in Barcelona, using crime statistics
from January 2018 to March 2021.

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## Methods:

We trained (seasonal) auto-regressive integrated moving average modelling (95% confidence intervals) using daily recorded crimes from January 2018 to February 2020. These models were then used to forecast crime data from March 2020 to March 2021 across four periods (lockdown, summer, fall and winter). Crime data were organized into two categories: property (burglary, theft) and violent crimes (robbery, assault, domestic violence and sexual offenses [rape, assault or abuse]).

## Results:

Overall, crime levels for property and violent crimes during lockdown declined sharply from the forecasted levels. Theft, burglary, assault, robbery and sexual offenses exhibited general decreases throughout the study period, with the same sharp declines during the lockdown, progressive recovery in the summer, and steady or slight reductions from fall to March 2021. Only domestic violence differed, reaching the forecasted levels for all periods and surpassing the forecast for summer 2020.

## Conclusions:

Our findings show how the pandemic has affected mid-term crime trends. They help to place the measures applied in the last year into context and to determine the most suitable policies to reduce crime during societal change.

## Introduction

Human behaviours, interactions, and movements are highly intertwined with the spread of infectious disease (Haug et al., 2020). The global spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) since December 2019 has led to governments imposing various measures to prevent virus transmission. These measures have deeply affected social structures and systems, disrupted the different segments of society, modified human activity, and changed multiple aspects of everyday life (Leach et al., 2021). Our understanding of these processes continues to progress slowly through the ongoing coronavirus disease 2019 (COVID-19) pandemic (Perra, 2021).

Once the World Health Organization (WHO) declared COVID-19 a global pandemic, governments and other actors deployed a cascade of preventive and reactive public health and social measures to curb the virus' transmission and relieve pressures on the healthcare systems and nursing homes. These non-pharmacological interventions, which included social distancing, quarantine, isolation, lockdown, and other mobility restrictions (e.g., curfew), proved effective in reducing the incidence of the virus (Haug et al., 2020).

Equally, however, they have resulted in multiple side effects on people's health, the environment, culture, the economy, labour markets and employment, equality, social interactions, and crime (Bambra et al., 2020; Bell & Blanchflower, 2020; Nivette et al., 2021), and can be understood through the lens of freedom-security unbalance (see Cheek et al., 2022). Research has shown that the most stringent measures (e.g., lockdown) are inconvenient and that it is often more suitable to use a progressive combination of less drastic containment measures, government help, and financial programmes tailored to the specific context and stage of the pandemic. Such an approach seems to offer the best way to curb the spread, reduce the costs, and mitigate the side effects of interventions (Haug et al., 2020).

The consequences of the pandemic provide an opportunity to reflect, transform, test, and advance criminological knowledge. Indeed, it can be seen as an externality, offering a natural social experiment, or also as an internality in terms of a chance to make visible the critical and alternative approaches beyond the dominant basis, assumptions, and epistemologies (Walklate, 2021). Criminology literature suggests various pathways whereby social and movement restrictions and policies related to shock events or emergencies can lead to a decrease in certain crimes and an increase in others, resulting in a temporary change to the crime landscape in urban areas. As a result, urban crime patterns have temporarily changed in different grades associated with the restrictions (Nivette et al., 2021).

Criminal opportunity, which is explained by the crime pattern, lifestyle, routine activities, and environmental design theories, is related to socio-environmental changes and structural and situational opportunities (Wilcox & Cullen, 2018). This framework explains how stay-at-home orders and social distancing measures can cause crime levels to fall due to the changes in urban mobility patterns and the strong disruption in the convergence of potential targets, perpetrators, and guardians and may also affect pre-existing individuals' behavioural dispositions. It is particularly noticeable in crime hotspots, reducing the density of daily encounters in the city where robbery, theft, assault, or nightlife-related incidents occur. Even so, the opportunity structures can differ across types of crime, thus a change in the opportunities for a specific type of crime may not imply changes in the opportunities for other crimes leading to acute changes in some of them and milder changes in others. There is also consideration of how rational choice mechanisms influence antisocial behaviour through hierarchical decision-making processes, with offenders choosing specific areas and targets linked to daily routines that are modified during the pandemic. This can be seen from a propensity-situational approach through the lens of situational action theory (Wikström, 2019), considering the divergent social conditions influencing the likelihood that individuals will engage in antisocial behaviours and, therefore, the possible differential impact on specific urban areas and communities. Reduced peer influence, increased monitoring, and formal social control to ensure compliance with containment measures can also drive or influence the individuals' willingness to take part in informal social control, which may contribute to reducing opportunities by fostering collective efficacy in a neighbourhood (Sargeant et al., 2021).

On the other hand, shock events like the COVID-19 pandemic may increase social disorganization and social deprivation, weaken social cohesion, and exacerbate inequalities and disadvantages depending on the population and community characteristics (Wenger,

2021). Multilevel stressors (i.e., psychological, economic, political, and financial), clustering, and/or intensifying previous burden (i.e., populations with structural inequalities and deprivation have also accompanied this context). For some populations, this has resulted in a syndemic (Singer et al., 2017), in which adverse conditions co-occur and interact to generate an integrated effect. As explained by the general strain theory (Agnew, 1992), this scenario can be a trigger for or can aggravate, negative emotions, which in turn, may affect the likelihood of antisocial behaviour and hinder adaptive behaviour in both the short and long term. The COVID-19 outbreak may also have triggered uncertainty and insecurity that may lead to anomie, given the inability of society to regulate social changes satisfactorily (Merton, 1938), mainly for individuals who experience difficulties. Governmental public health and communication policies have not always been adequately deployed and conveyed in situations where norms and scientific evidence change rapidly. Consequently, the pandemic could have increased factors that affect criminal propensity (individual and social problems and related stressors) depending on an individual's background, situational characteristics, and emotional regulation strategies (Sampson & Smith, 2021; Vertsberger et al., 2021).

The combination of criminal opportunity and propensity drives or prevents criminal behavior. The result of this interaction could vary across types of crime within a temporarily disrupted socio-ecological system where crime opportunity and motivation may have changed. Theoretically, due to the sudden drop in potential opportunities related to public spaces and daily life routines (Clarke, 2012), significant declines in property crimes and most of the violent ones are expected, namely for theft, robbery, burglary, and assault. At the same time, this has occurred at a time when opportunities have been displaced to residential facilities and online environments, especially during periods of lockdown. People have also spent more time at home, experiencing social isolation, emotional, economic, and financial stress, with reduced access to support because of the imposed restrictions, potentially increasing domestic and intimate partner violence, child abuse, and substance use and abuse (Pereda & Díaz-Faes, 2020; Piquero et al., 2021; Taylor et al., 2021).

Empirically, a growing number of studies have explored the variations in crime related to the COVID-19 pandemic in specific regions, countries, or cities. The first globally informed analysis was conducted by Nivette et al. (2021) using police-recorded crime mostly from Europe, Asia, and the Americas between January 2018 and May–June 2020. Their results revealed that crime levels fell worldwide in 27 major cities across 23 countries in association with stay-at-home orders, finding an average overall decline of −37% (overall effect size, 0.63). This study showed that crime declined substantially in most categories in each city from the beginning of the restrictions, especially in the theft and robbery domains (−47% and −46%, respectively), followed by motor vehicle theft (−39%), assault (−35%), burglary (−28%), and homicide (−14%). Nonetheless, their analysis unveiled important heterogeneity by city and crime type regarding both the direction and size of the crime trends. To address these differences, they contrasted a set of containment response policies as predictors of variation in crime levels, finding a negative association between the stringency of measures and the levels of crime. In other words, the most restrictive measures were associated with the greatest declines in crime. Nivette et al. (2021), as with other research works

(Abrams, 2021; Chen et al., 2021; De la Miyar et al., 2021; Hodgkinson et al., 2022; Langton et al., 2021a; Perez-Vincent et al., 2021; Shen et al. 2021), reported that the fall in crime in other countries or cities was short-lived, reaching its nadir after a few weeks and gradually recovering as restrictions ease, but this is not universal. Crime recovery can vary across types of crimes and locations. It also depends on other variables related to urban, social and economic dynamics. Extending the pandemic period to the end of 2020 and throughout 2021, we can distinguish between the studies that did not or showed different trends across types of crimes (Koppel et al., 2022 in New York City; Lopez & Rosenfeld, 2022 in the USA), those which generally recovered the pre-pandemic baseline levels (Buil-Gil et al., 2021 in Ireland; De la Miyar et al., 2021 in Mexico), and those that reported an overall increase (Paramasivan et al., 2022 in India). For example, Lopez and Rosenfeld (2022) used police data from 31 US cities from January 2017 to December 2020. There was a mean of 20 cities for all crimes – ranging from a minimum of 13 for domestic violence to a maximum of 28 for robbery – and found that property crimes decreased in all cities during the pandemic, except for motor vehicle crimes, which showed an upward trend after the stay-at-home orders of March 2020. Violent crime peaked in the summer of 2020 and declined thereafter.

On domestic and intimate partner violence, Piquero et al.'s (2021) meta-analysis first provided evidence suggesting that this type of incident increased by 7.9% (medium effect size, 0.66) after the stay-at-home orders based on official administrative pre–post records drawn from 18 studies. Negriff et al. (2022) found a significant increase in hospital admission related to child maltreatment just after the stay-at-home orders in California, followed by a gradual return to the pre-pandemic levels in September 2021. The trend for sexual violence is difficult to estimate and emerging evidence on this issue is mixed because several of its forms fall under other criminal typologies in official data sources. Studies covering these data during and after lockdown periods are scarce, Payne et al. (2022) in Australia, Abrams (2021) in the USA, and Shen et al. (2021) in Japan have all reported marked declines in sexual assault, while Hoehn-Velasco et al. (2021) noticed a U-shape trend of sexual crimes against women (including sexual assault and rape) in Mexico. At the same time, Ceccato et al. (2021) showed different patterns for rape in New York (V-shape trend), São Paulo (L-shape trend), and Stockholm (no sign of impact). Muldoon et al. (2021) noticed an increase in sexual assault in Ottawa based on emergency department admissions.

## COVID-19 restrictions in Barcelona

Based on data from public administrations and health agencies, we describe the stages and measures related to SARS-CoV-2 pandemic in the city of Barcelona (Agència de Salut Pública de Barcelona, 2021; Ajuntament de Barcelona, 2021a; IDESCAT, 2021). The first case of COVID-19 was detected on 25 February 2020, and the evolution of confirmed cases in Barcelona since the onset of the pandemic is shown in Figure 1. Educational institutions closed on March 13 and a stay-at-home order was implemented on March 15, under the state of alarm declared by the Spanish central government. Commonly known as lockdown, this period also entailed the temporary takeover of

industries and factories, closure of the borders, non-essential activity in retail businesses, bars and restaurants, and entertainment and leisure facilities (e.g., parks, cinemas, theaters, museums, night-time). Religious ceremonies and large gatherings outside and inside people's homes were prohibited. Two weeks later, restrictions were tightened, ordering non-essential workers to stay at home from March 30 to April 9. However, a portion of the workforce in sectors that did not work from home (e.g., industry, construction) were allowed to return to work on April 13. On May 2, a progressive period of easing of restrictions began, structured in four distinct de-escalation phases.

De-escalation Phase 0 was implemented until May 2, allowing the opening of certain commercial premises and the practice of individual sports out of the home. Phase 1, from May 25 to June 7, expanded the lifting of measures to allow family or friends to gather in groups of up to ten people, bars and restaurant's terraces to open at half capacity, hotels to reopen with common areas closed, and commercial premises <400 m² to reopen. In Barcelona, citizens were still not allowed to leave the city. During this phase (on May 21), the Ministry of Health imposed the mandatory use of masks in enclosed spaces and in public spaces where a minimum safety distance of 2 m could not be guaranteed. Phase 2 was in effect from June 8 to June 17 and allowed, among other things, mobility within the Barcelona metropolitan area (5,627,638 inhabitants), malls to reopen with limited seating capacity, consumption to resume within bars and restaurants, and flea markets to reopen. On June 18, Phase 3 began and significantly lifted previous
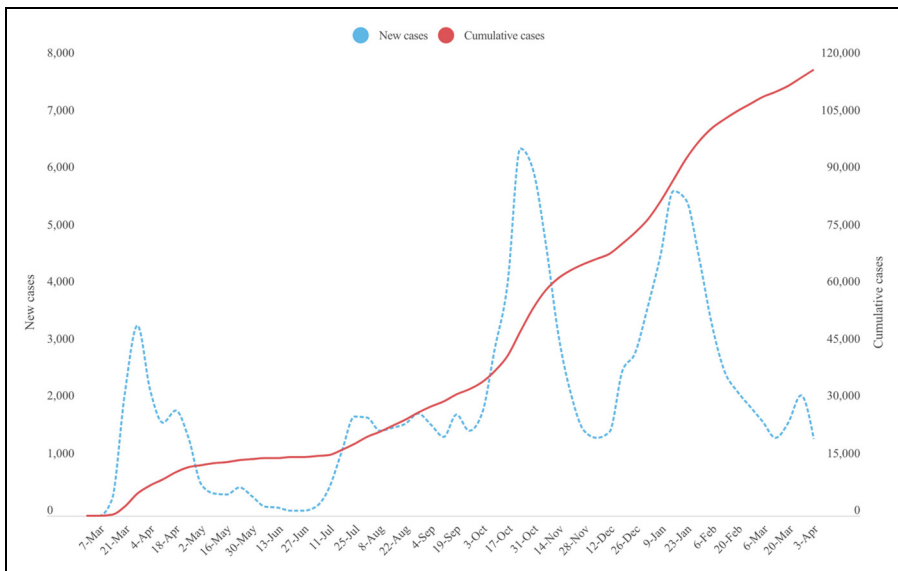


**Figure 1.** New and cumulative confirmed coronavirus disease 2019 (COVID-19) cases in Barcelona from March 2020 to March 2021 inclusive. The four periods of interest are differentiated by dashed lines on March 15 (lockdown), June 21 (summer), September 21 (fall), and December 31 (winter).
Source: Agència de Salut Pública de Barcelona (2021).

restrictions, allowing activities in commercial premises and nightlife venues, and mobility within the Catalan territory for the first time since the lockdown began. The next day, on June 19, Catalonia entered a new stage called "new normality," and two days later, the state of alarm finally expired. Coinciding with the summer period, this marked a 4 months period of less restrictive measures, albeit with some oscillations. For example, on July 9, the use of face masks in public spaces became compulsory again, with a new safety distance of 1.5 m, after being lifted on June 26. Eventually, due to the rise in cases, more restriction measures were ordered (e.g., closure of bars and restaurants on October 16), and a new state of alarm was finally imposed on 25 October 2020, which would last for several months. This mainly included a night curfew, restrictions on mobility within Catalonia, and gatherings in public spaces, but falling short of a full lockdown. The government started vaccination campaigns on 27 December 2020, and extended the second state of the alarm to 9 May 2021. Table 1 summarizes the timeline of periods and main policy changes.

The changes in containment policies affected mobility, highlighting the potential shift effect on criminal opportunity. As shown in Figure 2, mobility data reveal how people moved around and used public and private spaces. The trends in mobility shifted markedly during the lockdown, with time spent in residential facilities increasing and time spent in all other settings plummeting. By contrast, mobility came closer to the baseline value in the summer before falling off again in October 2020 due to the re-entry of some restrictions. Finally, mobility exhibited an upswing from baseline in November, with a further fall in December and a subsequent recovery toward baseline.

## The current study

We aim to understand crime changes related to the COVID-19 policy response using data until 15 March 2021. As Nivette et al. (2021) suggested in their meta-regression analysis focused on the lockdown period using official records, Barcelona may be a potential outlier across the 27 cities examined. Barcelona experienced the second overall crime decline despite not being the city with one of the most stringent measures. This case is of interest to assess how the change of containment policies over time affected crime and its recovery. We had two major hypotheses:

(A) There will be a general decline in crime levels, especially during the lockdown and for property crimes. Domestic violence will be the unique exception to this trend.

(B) Crimes will not completely recover the pre-pandemic levels at any point during the period analysed, and the forecasted and observed crime levels will diverge. Again, domestic violence will follow a different pattern.

## Method

### Data

This study analyses whether the trend of daily recorded crime by Catalonia's police force (*Mossos d'Esquadra*) in the city of Barcelona (1,664,182 inhabitants)

**Table 1.** Summary of periods and policy changes.

| | Lockdown | Summer | Fall | Winter |
|---|---|---|---|---|
| Dates | 15 March to 21 June 2020. | 22 June to 21 September 2020. | 22 September to 31 December 2020. | 1 January to 14 March 2021. |
| Stringency | Most restrictive period. | Least restrictive period, the 'new normality' phase. | Milder restrictive period. | Milder restrictive period. |
| State of alarm | Yes. | No. | Yes. | Yes. |
| Features | The first state of alarm. Confinement. Mandatory face mask wearing. Travel restrictions and closure of the borders. Non-essential activity is allowed. Educational centres closed. | The state of alarm expired on June 21 | The second state of alarm was imposed on October 25th. | The second state of alarm extended. |
| Main changes over the period | Some minor restrictions were lifted in mid-April. Beginning of the de-escalation in May, phase by starting date #0 (May 24), #1 (May 25), and #2 (June 8). | On July 9, the mandatory wearing of face masks in public spaces was reimposed due to the rise in covid diagnosed cases. | A sharp increase in diagnosed covid cases by the end of September. New restrictive measures prior to the second state of alarm. | Vaccination campaigns started on December 27. |

changed due to the containment policies (during lockdown, i.e., March 15 to June 21 2020) and during the rest of the COVID-19 pandemic (post-lockdown; including summer, fall, and winter). The first data point for the current database was 1 January 2018, and the most recent addition was on 31 March 2021. These data, therefore, covered a year after the COVID-19 pandemic was declared by the WHO on 11 March 2020 and a period after the 3-month lockdown period from 15 March to 21 June 2020.

We focused on daily offense records for 15 types of crimes (Table 2). The official data provided by the police included both consummated crime (e.g., killing a person with a knife) and attempted crime (e.g., sticking a knife in a vital area with an intention to kill, but where the victim survived). However, they do not include crimes committed through imprudence (e.g., if a flowerpot is thrown from a balcony and kills someone or if the facts do not show a clear intent to kill).
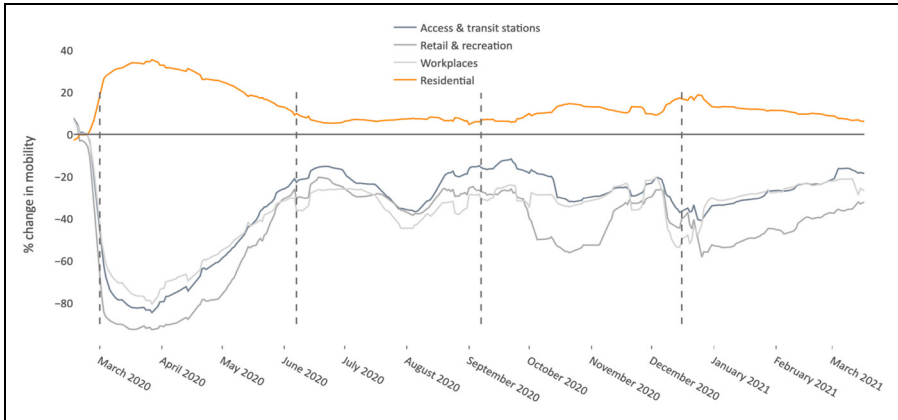
**Figure 2.** Median percentage change in mobility from baseline in Barcelona between March 2020 and March 2021. Source: Google (2021), and Agència de Salut Pública de Barcelona (2021). Note: An additive seasonal decomposition was applied to the raw time series data.

**Table 2.** Crime categories and definitions.

| Crime | Definition |
| --- | --- |
| Asault | Threatening or assaulting another person. |
| Burglary (commercial) | Stealing an object by force from a commercial establishment. |
| Burglary (residential) | Stealing an object by force from someone's home. |
| Burglary (in other places) | Stealing an object by force from places other than shops or homes. |
| Domestic violence | Violence against the partner or other relatives within the family. |
| Intentional homicide | Intentionally killing another person. |
| Motor vehicle theft | Stealing a motor vehicle. |
| Robbery (commercial) | Stealing from a commercial establishment using physical violence or intimidation against people. |
| Robbery (residential) | Stealing from someone's home using physical violence or intimidation against people. |
| Robbery (in other places) | Stealing from other places than shops or homes using physical violence or intimidation against people. |
| Sexual abuse | Sexual offense against another person without using violence or intimidation, but not having the victim's consent. |
| Sexual assault/rape | Sexual offense against another person using violence or intimidation. |
| Thefts (commercial) | Stealing from a commercial establishment without using violence or force. |
| Thefts (residential) | Stealing from someone's home without using violence or force. |
| Thefts (in other places) | Stealing from other places that are not shops or homes without using violence or force. |

## Analytical approach

To assess changes in daily police-recorded crime due to the pandemic restrictions and to draw conclusions at the macro level, we first grouped the 15 individual offenses into two main categories depending on the nature of the crime: a) property crime, which includes thefts (i.e., residential theft, commercial theft, theft in other places, motor vehicle theft) and burglaries (i.e., residential burglary, commercial burglary, burglary in other places); and b) violent crimes, which includes intentional homicide, assault, robberies (i.e., residential robbery, commercial robbery, robbery in other places), domestic violence, and sexual offenses (including sexual abuse and rape/sexual assault). Furthermore, we selected four different periods of interest: the lockdown period (15 March to 21 June 2020) and the three post-lockdown periods, which we split into summer (22 June to 21 September 2020), fall (22 September to 31 December 2020), and winter (1 January to 14 March 2021). Then, we visually inspected the daily offense records of property and violent crimes for the three full calendar years with available data (2018–2020); see Figure 3 for property crimes and Figure 4 for violent crimes. In addition to visualizing the raw data, we performed an additive STL decomposition (i.e., trend, seasonality, and residual) of time series for both the aggregate property and violent crimes using the seasonal-trend decomposition using locally estimated scatterplot smoothing to compute smooth estimates of the three components, more specifically the implementation within the *statsmodel* Python module. That is, we decomposed each time series as a sum of the trend, seasonality, and residual components, which we
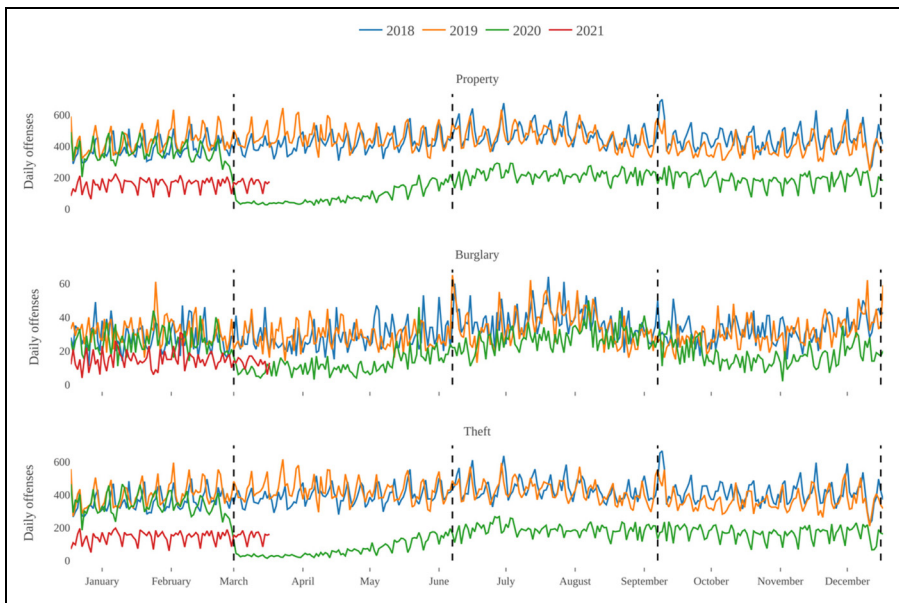


**Figure 3.** Recorded daily property crimes for 2018–2021. The four periods of interest are differentiated by dashed lines on March 15, June 21, September 21, and December 31.
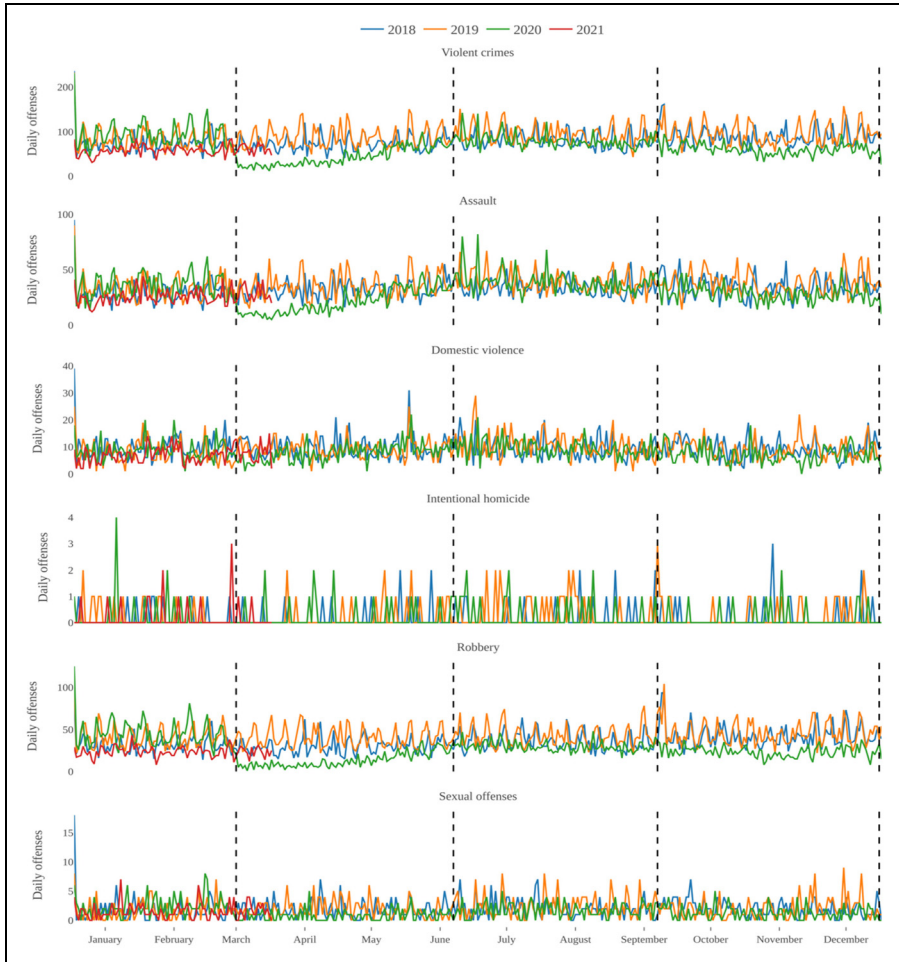
**Figure 4.** Recorded daily violent crimes for 2018–2021. The four periods of interest are differentiated by dashed lines on March 15, June 21, September 21, and December 31.

repeated for both crime categories and for each calendar year, and depicted only the trend component, see Figure 5. The trend helped to visualize and assess quantitatively how the observed variable changed over a given period (e.g., summer or fall) in different years.

We computed forecasts for each aggregated category (property and violent crimes) and offense (thefts, burglaries, intentional homicide, assault, robberies, domestic violence, and sexual offenses) by training separate auto-regressive integrated moving average (ARIMA) models on the weekly number of offenses recorded from 1 January 2018 to 29 February 2020. ARIMA models have been extensively used to forecast time series for crime data during the COVID-19 restrictions when assessing changes in crime trends (Ashby 2020; Payne et al., 2021, 2022). For a given offense category,
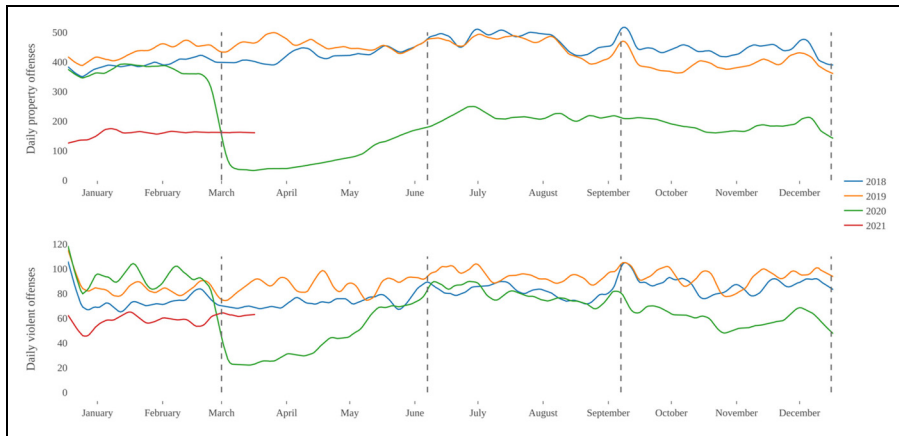
**Figure 5.** Recorded property crime (top) and violent crime (bottom) trends for 2018–2021. The four periods of interest are differentiated by dashed lines on March 15, June 21, September 21, and December 31.

these models leverage the trend, seasonality, and lagged autocorrelation (i.e., the correlation of observations separated by time within a given time series) of the observed time series to produce forecasts with confidence intervals for unobserved periods. A key assumption of this process is that there is an underlying relationship between past and future data, whereby the ARIMA model learns the key aspects of the observed time series to produce accurate predictions. Once forecasts have been computed for each crime category, we can quantitatively assess the significance of the difference between the observed and predicted crime levels based on past data (e.g., what would have happened if COVID-19 had not occurred).

First, for each crime category, we ascertained whether the time series exhibited trend and/or seasonal effects, also known as non-stationarity or the presence of a unit-root. If a series contains a unit-root, then a shift in time causes a change in the distribution of the series, and thus needs to be trend and/or seasonally differenced before fitting an ARIMA model. For trend effects, we performed several unit-root tests to determine the order of differencing $d$ to make a given time series stationary, namely the augmented Dickey-Fuller test, the Kwiatkowski-Phillips-Schmidt-Shin test, and the Phillips-Perron test, since there is often conflicting evidence of trend stationarity between different unit-root tests. For seasonal effects, we performed an Osboi-Chui-Smith-Birchenhall test to estimate the number of seasonal differences $D$ to make the time series stationary. Hence, for each crime category, we had three different values for $d$ (one per test) and one value for $D$, and a 0.05 significance was used for the tests.

Second, for each crime category, we trained ARIMA[$p,d,q$] and seasonal ARIMA (SARIMA)[$P,D,Q$, 52] models to account for trend and seasonality, respectively, using the Python package *pmdarima* (Smith, 2017). These were trained on the weekly total recorded crimes from 1 January 2018, to 29 February 2020 (hence a seasonal periodicity of 52). The auto-regressive $p/P$-parameters capture the number of prior observations

included in the model to predict future values, the integrative (I) *d/D*-parameters measure the number of times the raw data is differentiated to correct for trend and seasonal stationarity, and the *q/Q*-parameters represent the size of the moving average window. Since there were three distinct differencing parameters *d/D* given by the trend and seasonal stationarity tests performed above, for each one we followed the stepwise algorithm outlined by Hyndman and Khandakar, 2008 to find the configuration $\{p, P, q, Q\} \in \{0, 2\}$ that provided the best fit to the data. The information criterion chosen to select the best parameter configuration is the Akaike Information Criterion (AIC), which is one of the most extensively used for estimating the error of a time series forecast model. After training the three different models for each crime category, we chose the configuration of parameters $\{p, d, q, P, D, Q\}$ with the lowest overall AIC, which was the model used for forecasting. The only crime category for which a model is not trained is intentional homicide because the incidence of these crimes is too low to produce accurate forecast models. The optimal configuration of ARIMA parameters chosen for each crime category is collected in Table 3.

Finally, for each crime category, we used the ARIMA–SARIMA model trained with the best set of parameters, that is those that minimize the AIC, to predict the estimated weekly recorded crimes, along with the 95% confidence intervals, for the period from 1 March 2020, to 14 March 2021. We then compared the forecast and observed values for the four seasonal periods and considered whether a significant change occurred (at the 5% level) in the offense rate if the observed crimes fall outside the upper and lower bounds on the confidence interval, as aggregated for the period of interest. It should be noted that confidence intervals widen the further in the future we forecast, thus signalling greater confidence for predictions that are close in time to the end of the training period (29 February 2020).

## Results

### Observed trends of daily recorded crimes

Similar crime trends are observed for 2018 and 2019, see Figure 5, while 2020 clearly shows a distinct pattern. Interestingly, the data shows a point increase on January 1 for both property and violent crime. The recorded property crimes in the first five months

**Table 3.** Optimal parameter configuration of ARIMA [*p,d,q*] and SARIMA [*P,D,Q*,52] models.

| | Type of crime | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Property | | | Violent | | | | |
| | Burglary | Theft | Overall | Assault | Domestic | Robbery | Sexual | Overall |
| [*p,d,q* ] | [1,0,0] | [0,1,1] | [0,1,1] | [0,1,1] | [0,0,0] | [0,1,1] | [1,0,0] | [0,1,1] |
| [*P,D,Q* ] | [1,0,0] | [1,0,0] | [1,0,0] | [0,0,0] | [0,0,0] | [1,0,0] | [0,0,0] | [2,0,0] |

ARIMA: auto-regressive integrated moving average; SARIMA: seasonal auto-regressive integrated moving average.

of 2019 were 11% higher than in 2018, 4% lower from June to September, and 11% lower from September onwards, rendering roughly the same total number of crimes for both years. Conversely, the number of violent crimes in 2019 increased by 14% compared to 2018.

In 2020, before the lockdown, property crime was 7% lower and violent crime was 23% higher than for the same period in 2018, whereas compared to 2019, they were 16% lower for property crime and 8% higher for violent crime (see Table 4).

From mid-March to late June 2020, we observed a sharp decline in recorded crimes for both categories (around 80% for property crimes and 40–50% for violent crimes compared to the same period in the previous two years). Overall, despite increasing from the minimum figures attained at the end of March, the aggregated volume of both crimes from 22 June 2020 onwards did not reach the levels recorded in previous years. The data show approximately 55% fewer property crimes in the summer 2020 period than in the previous two years, whereas violent crimes rose to the same levels as in 2018 (albeit 16% lower than in 2019). In the fall of 2020, both property and violent crimes decreased compared to the summer 2020, roughly 55% and 34% compared to the same period in previous years. Overall, during the lockdown, both property and

**Table 4.** Daily recorded property and violent crimes for four periods across three years, with comparisons shown for 2020 and 2021.

| | Property crimes per day | | | | Violent crimes per day | | | |
|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2018 | 2019 | 2020 | 2021 |
| Winter | 390 | 433 | 362 −7% 2018 −16% 2019 | 157 −60% 2018 −64% 2019 −57% 2020 | 74 | 85 | 91 +23% 2018 +8% 2019 | 57 −23% 2018 −32% 2019 −37% 2020 |
| Lockdown | 423 | 457 | 81 −81% 2018 −82% 2019 | – – – – | 73 | 87 | 44 −39% 2018 −49% 2019 | – – – – |
| Summer | 475 | 459 | 216 −54% 2018 −53% 2019 | – – – – | 81 | 95 | 80 −2% 2018 −16% 2019 | – – – – |
| Fall | 446 | 394 | 184 −59% 2018 −53% 2019 | – – – – | 88 | 94 | 60 −32% 2018 −36% 2019 | – – – – |

violent crimes plummeted, showed a progressive recovery during the summer (especially for violent crimes) and decreased again in the fall, never reaching the minimum values observed at the end of March 2020, see Figure 5 and Table 3.

Data for the 2021 winter period showed lower levels of both property and violent crimes compared to the same period in previous years (60% for property crimes and 25–40% for violent crimes). Furthermore, less property crimes in the winter of 2021 occurred compared to the fall of 2020 (declining from 184 per day in the fall of 2020 to 157 per day in the winter of 2021), whereas the number of violent crimes remained fairly static between these periods.

## Forecasted trends of weekly property and violent crimes

We used the ARIMA models trained on data from 1 January 2018, to 29 February 2020, for each crime category to predict the number of offenses in the remainder of 2020 and the first three months of 2021. This simulated a counterfactual scenario without the COVID-19 pandemic. We then compared the weekly forecasts and observed data, presenting the aggregated results across the four study periods, see Figures 4 and 5) We also show the 95% confidence intervals for the forecasted data, which we leveraged to assert whether the observed crime data were significantly lower or higher (i.e., outside the confidence interval) than the forecasted data for each crime category and period. Finally, we report the percent change in weekly observed crimes regarding the mean forecasted value for each period and crime.

***Change in weekly observed crimes.*** Table 5 shows the percentage change in weekly observed crimes with respect to the mean forecasted value for each period and crime.

***Property crimes.*** The decline in property crimes for the lockdown and summer 2020 periods was significant compared to that predicted from historical data, see Figure 6. Despite lower-than-forecasted values for property crime in the fall 2020 and winter 2021 periods, this was insufficient to conclude on its statistical significance. Observed burglaries and thefts exhibited a significant decline during the lockdown compared to the aggregated predictions, and although observed thefts increased in the summer, they remained significantly lower than the forecast levels. Conversely, burglaries recovered to pre-pandemic levels in the summer. Although the observed burglaries and thefts

**Table 5.** Relative weekly change in observed crimes, by type, using mean forecasted data for 2018–2021.

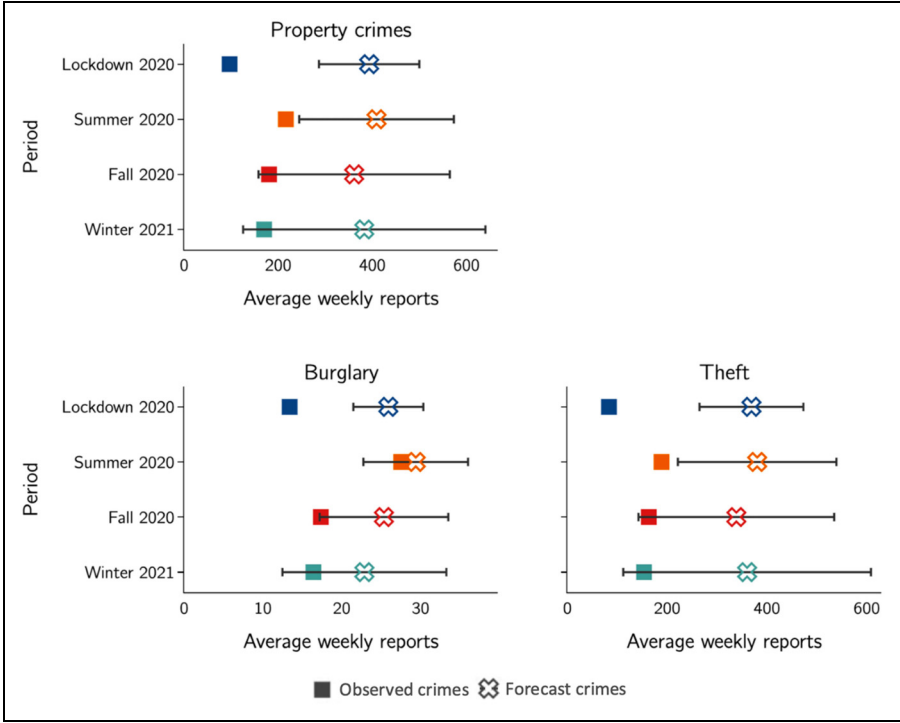| | Type of crimes | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Property | | | Violent | | | | |
| | Burglary | Theft | Overall | Assault | Domestic | Robbery | Sexual | Overall |
| Lockdown 2020 | −48% | −77% | −75% | −44% | +0.4% | −67% | −72% | −50% |
| Summer 2020 | −6% | −50% | −47% | −5% | +19% | −38% | −50% | −19% |
| Fall 2020 | −32% | −52% | −50% | −31% | −8% | −54% | −60% | −43% |
| Winter 2021 | −28% | −57% | −43% | −38% | −3% | −54% | −55% | −45% |

**Figure 6.** Forecast weekly property crimes (crosses, with 95% confidence intervals) compared to observed property crimes (squares), aggregated into four periods for comparison. Data are shown overall (chart above) and by type of property crime (two charts below).

values in fall and winter were lower than the estimated means, we have insufficient evidence to assert that these were statistically significant at the 95% level.

*Violent crimes.* A statistically significant decline occurred during the lockdown compared to the forecast, see Figure 7. The observed violent crime data were still lower than the point estimates using the forecast models in summer, fall, and winter; however, all values were within the confidence intervals, precluding comment on the significance of this decline. Assault and robbery exhibited the same pattern of a significant decrease during the lockdown, recuperation in the summer (almost to pre-pandemic levels for assault, but still significantly lower for robbery), followed by a further decrease in the fall and winter that was still above the minimum observed during lockdown (and only significantly lower than pre-pandemic levels for robbery). Sexual offenses followed the same pattern, recovering in the summer from the minimum during lockdown and decreasing again in the fall and winter; however, no changes were significantly lower than the forecast data. Finally, domestic violence exhibited a distinct behaviour, with the observed 2020 values coinciding with the estimated forecasts across all four periods and showing an even greater, albeit non-significant, number of observed crimes in the summer.
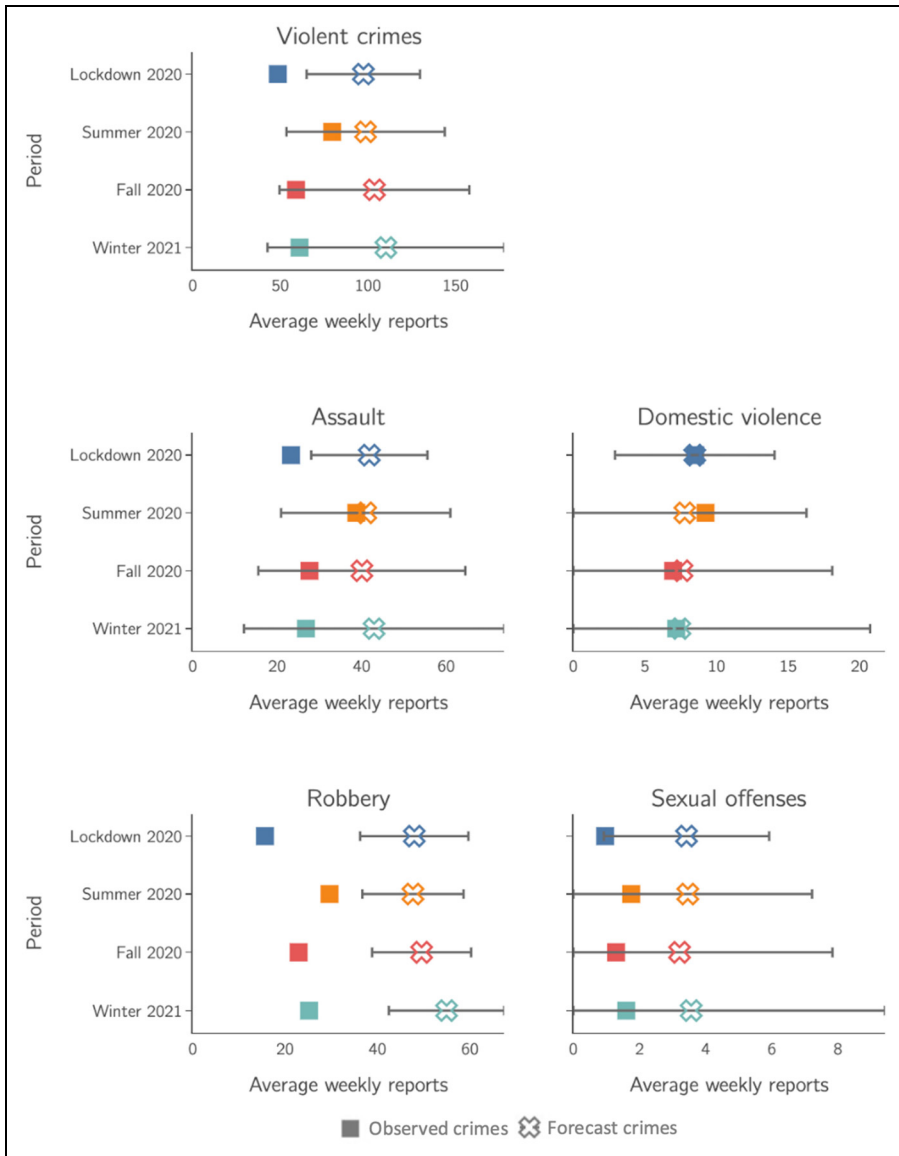
**Figure 7.** Forecast weekly violent crimes (crosses with 95% confidence intervals) compared to observed violent crimes (squares), aggregated into four periods for comparison. Data are shown overall (first above) and by type of violent crime (four charts below).

## Discussion

The COVID-19 era has led to an unprecedented drop in short-term crime trends in many regions worldwide, though this is neither homogeneous nor universal. Since the 1990s,

highly industrialized Western societies have seen a notable and constant downward trend in most traditional types of crime (van Dijk et al., 2021), while cybercrime has grown in parallel (Caneppele & Aebi, 2019). Bearing in mind that various gaps persist in the data infrastructure, limiting the capture and description of crime trends, as well as the analysis of explanations for changes (Baumer et al., 2018), the nature of this relationship remains unclear and the COVID-19 pandemic seems to have reinforced the upward trend in cybercrime (Buil-Gil et al., 2021).

The present study is one of the few works to have focused on analyzing crime trends in the COVID-19 pandemic over the mid-term. We included not only crime-recorded data during the lockdown but also year-on-year comparisons and seasonal variations. This has allowed us to see how a singular and unique event, the COVID-19 pandemic, and the measures taken to prevent its spread, affected different types of crime based on officially recorded data. In this regard, official police-recorded crime data are associated with underreporting, mediated by crime definitions, the nature of police work (e.g., discretionary or operational priorities), and reporting rates that vary by the types of crime. Well-known problems, such as a victim's willingness to report or the performance and practices of the justice and health system, can affect crime reporting and recording. This can lead to reporting variations that are dependent on the type of crime and influenced by victimization and harm, the external environment, and personal or household characteristics (Xie & Baumer, 2019).

Not all population groups and victim types are as likely to report to the same extent under normal conditions, with differences known to exist between the young and elderly, women experiencing intimate partner violence, and minority and non-minority groups (Díaz-Faes & Pereda, 2022; Goudriaan & Nieuwbeerta, 2007; Katz et al., 2021; Leon et al., 2022); moreover, these differences may have worsened during the pandemic. Additional barriers to a victim's willingness to report interpersonal crimes during the pandemic have been found, including fear of infection, lockdown requirements, disrupted resources, how to report, and subsequent alternatives, which may preferentially affect isolated children and adolescents, women, or the elderly living in nursing homes. In addition, the low availability of police officers and the stressors they are exposed as well as the severe restrictions on resources and priorities during the pandemic have influenced the reports (Frenkel et al., 2021; Laufs & Waseem, 2020; Maskály et al., 2021). Indeed, despite government-driven policies and media campaigns to promote reporting during and after the lockdown, some studies have shown an overall decrease in crime-related calls to the police during lockdown (Ashby 2020; Dai et al., 2021). At present, the effects of the pandemic on the under- and over-reporting of crime remains unclear.

The results of this study can be discussed both in general and specific terms. As hypothesized, the general decline of around 80% for property crimes and 40–50% for violent crimes has been found when comparing March to June 2020 with the same period in the previous 2 years, confirming post-lockdown evidence that is emerging (Nivette et al., 2021). This sharp decline was expected due to the mass lockdown and stay-at-home policies, and the ARIMA–SARIMA models confirmed this trend, finding a statistically significant drop in property and violent crimes during the lockdown that persisted to the summer for property crime. In connection with the lifting of measures

in summer, we expected crime levels to show a sudden and temporary increase, but much less than the forecast levels as we had hypothesized. To different degrees, we observed similar patterns during the four periods analysed for all crime types (i.e., burglary, theft, robbery, assault, and sexual offenses), but not for domestic violence. That is, they increased throughout the lockdown, peaked in summer (end of June 2020) alongside the post-lockdown period, and further decreased or stabilized in the fall and winter. However, none reached the predicted levels. With the reintroduction of containment policies on 25 October 2020, recorded crimes for theft, burglary, assault, robbery, and sexual offenses exhibited general decreases in the same pattern (decrease during the lockdown, a subsequent increase in summer, followed by a slight reduction or stabilization until March 2021). Only domestic violence showed a distinct pattern, reaching the forecast levels in all periods, even overcoming it in the summer 2020 and showing a greater (albeit non-significant) number of observed crimes after the lockdown. The observed trends result from socio-ecological changes and opportunity structures rapidly mediating short-term outcomes through a shift in urban mobility (see Figure 2). The changing scenario and the containment measures likely drove the low crime levels through criminal opportunity near-mechanisms and interrupted antisocial peer association linked to reduced activity in public spaces and disrupted social interactions.

Compared to the evidence available on recovery levels, the only European study covering part of 2021 (Buil-Gil et al., 2021) showed that conventional offline crimes recovered their pre-pandemic levels after the lockdown downfall and mobility recovery, which contrasts with our findings. Most of the included crimes are highly associated with economic, urban and nightlife activity. Barcelona ranks among the main tourist destinations for international visitors across Europe (Ajuntament de Barcelona 2022). After the tourism growth in the mid-1990s, a sharp increase in the 2000s, tourism, gentrification, and related processes experienced rampant growth last years, where short-term rentals and the formation of 'foreign only' enclaves grew throughout the city (Cocola-Gant & Lopez-Gay, 2020), mainly in the historic centre and its surroundings, the districts of Ciutat Vella, Eixample and some areas of Gràcia and Sants-Montjuic. This transnational gentrification has also caused extremely low ratios of local population in some neighbourhoods, as in the Raval and Gòtic. Such dynamics can play key roles in crime levels, as Maldonado-Guzmán (2020) suggested by analyzing the density of Airbnb lodgings positively associated with higher crime rates, especially property crime.

Such effects have been partially disrupted during the pandemic. As Langton et al. (2021b) reported using data from England and Wales, city centres experienced the sharpest drop because of the drastic reduction of crime opportunity structures. These changes in the urban dynamics may have been greater and lasted in Barcelona than in other major cities because they are more linked to tourism and travel, thus contributing to understanding why crime levels have remained far below. For instance, during the period analysed (until March 2021), despite the gradual recovery of visitors, Barcelona was still far from the pre-pandemic levels of tourism (Ajuntament de Barcelona, 2021b). A clear example is the low recovery of theft, the most common recorded crime and the one typically related to target density. Leisure activities, social gatherings, nightlife, and the linked use of alcohol and drugs have been interrupted, reduced, or lost during the pandemic, reducing the potential for interaction- and dynamic-related conflict, as well as

violent incidents in public spaces (Miller, 2013). In this sense, Ejrnæs and Scherg (2022) showed how the level of nightlife economy restrictions and the density of alcohol outlets in the area significantly affect the frequency of violent crime in Copenhagen. Gerell et al. (2022) also found in Oslo that both, general restrictions and banning of alcohol sales, were negatively associated with crime, albeit this was not true for all types of offenses and times of the day. The findings suggest that both, general restrictions and bans on serving alcohol, reduced crime, although not universally across all crime types and times of the day.

Domestic violence presented a different pattern to the other crimes, showing a greater increase in observed levels after the lockdown compared to previous years. Though non-significant, with the potential to differ across specific groups and contexts (Baglivio et al., 2021), this result is consistent with metanalytical evidence (Piquero et al., 2021). This can be partially explained by the increase in opportunity in residential facilities given the strong shift in mobility towards them and the convergence of multiple stressors in volatile context. Strain and related mechanisms may have mediated the increase in domestic violence, while stay-at-home measures and lasting disruptions to alternatives and resources may have reduced the likelihood of reporting. Trying to understand the nature of domestic abuse from police records is problematic because many incidents are underreported (Felson et al., 2002). Other studies provide evidence of barriers to formal help-seeking behaviour for domestic violence during the lockdown and remote working periods (Vives-Cases et al., 2021), with online survey data showing a 23% increase in intimate partner violence (Arenas-Arroyo, 2021). Sexual offense recorded crimes must be interpreted with caution because formal reporting rates are typically low (Kelley et al., 2021). However, this reporting may have been even worse during the pandemic and may have even varied among sexual abuse, assault, and rape, with previous studies showing different rates and trends (Ceccato et al., 2021; Hoehn-Velasco et al., 2021).

In summary, despite the complexity of comparing different cultural contexts and local dynamics in urban areas, we found that conventional crime levels in the extended post-lockdown period in Barcelona showed a downtrend trend consistent with previous studies analyzing different types of crimes but differing in recovery levels according to city characteristics and activity as exposed. This can be, at least, partially explained by the opportunity and stress frameworks but need further examination, such as spatio-temporal analysis for specific types of crimes and locations, given the multiple intervening factors and the possible variations across social contexts and timelines (Regalado et al., 2022). Findings are generally consistent with the opportunity theories for property crimes and the violent crimes linked to urban activity and target density, especially concerning lifestyle-routine activities theory. Domestic violence levels may be in line with the general strain theory principles, particularly during the lockdown, although the increase in cases in our study is non-significant. Socio-ecological models are valuable for a nuanced interpretation across types of crimes and specific contexts. For public policy, the present study is informative about how crime trends can change according to their typology, the policy measures deployed, and the characteristics of the urban area. They are also instructive about the potential pull–push mechanisms to prevent the associated effects and anticipate the areas in which focus efforts.

This pandemic has confirmed the uncertainties, flaws, and fragilities of the current systems, emphasizing the need to build a future based on sustainability, social justice, and improve care for behavioural, emotional, social, and mental health (Leach et al., 2021; Ndumbe-Eyoh et al., 2021). The socioeconomic and health effects of the COVID-19 pandemic may increase long-term offending and victimization in the most vulnerable due to existing disparities related to the rise of inequality, individual and community poverty, low income and unemployment levels, economic stress, and weakened health systems (Pratt & Cullen, 2005; Richmond-Rakerd et al., 2020; Sayed & Peng, 2021). Furthermore, mainstream research on crime and violence needs to focus on structural variables (e.g., culture, race, gender, class, or minority identities) to better examine, deconstruct, and understand these phenomena, their implications, and the related nuances (Walklate, 2021).

## Limitations

First, our study relied on police-recorded crimes, which have important structural and procedural limitations. However, self-report data, such as the Barcelona Victimization Survey (Enquesta de Victimització de Barcelona, Ajuntament de Barcelona, 2021c), has also shown a significant decrease in most crimes in 2020 compared to the previous two years. The only difference might be domestic violence, where studies based on Spanish self-reports have shown significant increases (Arenas-Arroyo et al., 2021) that are not found in official records. Nevertheless, this trend seems to vary by province (Vives-Cases et al., 2021) and study, with the need to include more cities in the same country to clarify this result Second, we did not assess other interpersonal violence events or cybercrime in the present study or compare crimes based on residential and commercial locations. Third, in terms of the analytical approach, our forecast models relied entirely on crime data recorded from 2018 onwards. Hence, the conclusions drawn assume that crime records from 2018 until February 2020 are representative of the crime trends in Barcelona, which influences the robustness of the predictions. Furthermore, we only had limited certainty of distant forecasts (e.g., winter 2021) due to the broad confidence intervals. Finally, analyzing short periods of time does not allow us to account for longer-term trends or seasonal variations, potentially creating masked or exaggerated effects (Payne et al., 2022). Despite these limitations, we believe that the present study contributes to the international body of knowledge of how the COVID-19 pandemic has affected crime levels, being one of the first studies worldwide to analyse it during a wide period.

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