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The Initial and Dynamic Effects of the COVID-19 Pandemic on Crime in New Zealand

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Abstract

We use seasonal ARIMA methods to study the imposition and removal of national uniform social distancing restrictions in response to Covid-19 in New Zealand for six crime types in six cities. We then use the estimated models to forecast counterfactual crime trajectories. Novel elements include cleanly defined lockdown periods, two distinct lockdowns with meaningful gaps between them, and sizeable periods after each one to allow for dynamics. We find that social restrictions initially lower offending, subsequent lockdowns have smaller impacts on offending, "bounce back" occurs in criminal offending after their removal, and bounce back is faster from subsequent lockdowns.

JEL classification: C22, H75, K14, K42

Keywords: COVID-19; lockdown; crime; counterfactual; bounce back

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1 Introduction

There is a growing body of studies showing that across many countries and categories of crime that behavioural changes and social distancing restrictions in response to COVID-19 initially significantly reduced overall crime rates, although with substantial variation across locations and types of crime. But, while it is clear that the restrictions placed upon what people can do and where they can go has initially reduced overall criminal activity, it is not clear what happens once those same restrictions are relaxed.

Available studies to date document falls in overall crime rates in the United States (Ashby (2020); Piquero et al. (2020); Mohler et al. (2020); Abrams (2021)), Australia (Payne et al. (2021); McCarthy et al. (2021)), the United Kingdom (Halford et al. (2020); Langton et al. (2021)), Sweden (Gerell et al. (2020)), Canada (Hodgkinson and Andresen (2020)), and New Zealand (Cheung and Gunby (2022)). Reinforcing the findings of these studies from a wider global perspective is Nivette et al. (2021), who assess the initial impacts of lockdown style restrictions on criminal activity in 27 cities across 23 countries. Not all crime categories have fallen though, with categories such as cyber-crime (Lallie et al. (2021)), and in some locations, domestic violence, often found to have risen (Leslie and Wilson (2020); McCrary and Sanga (2021)).

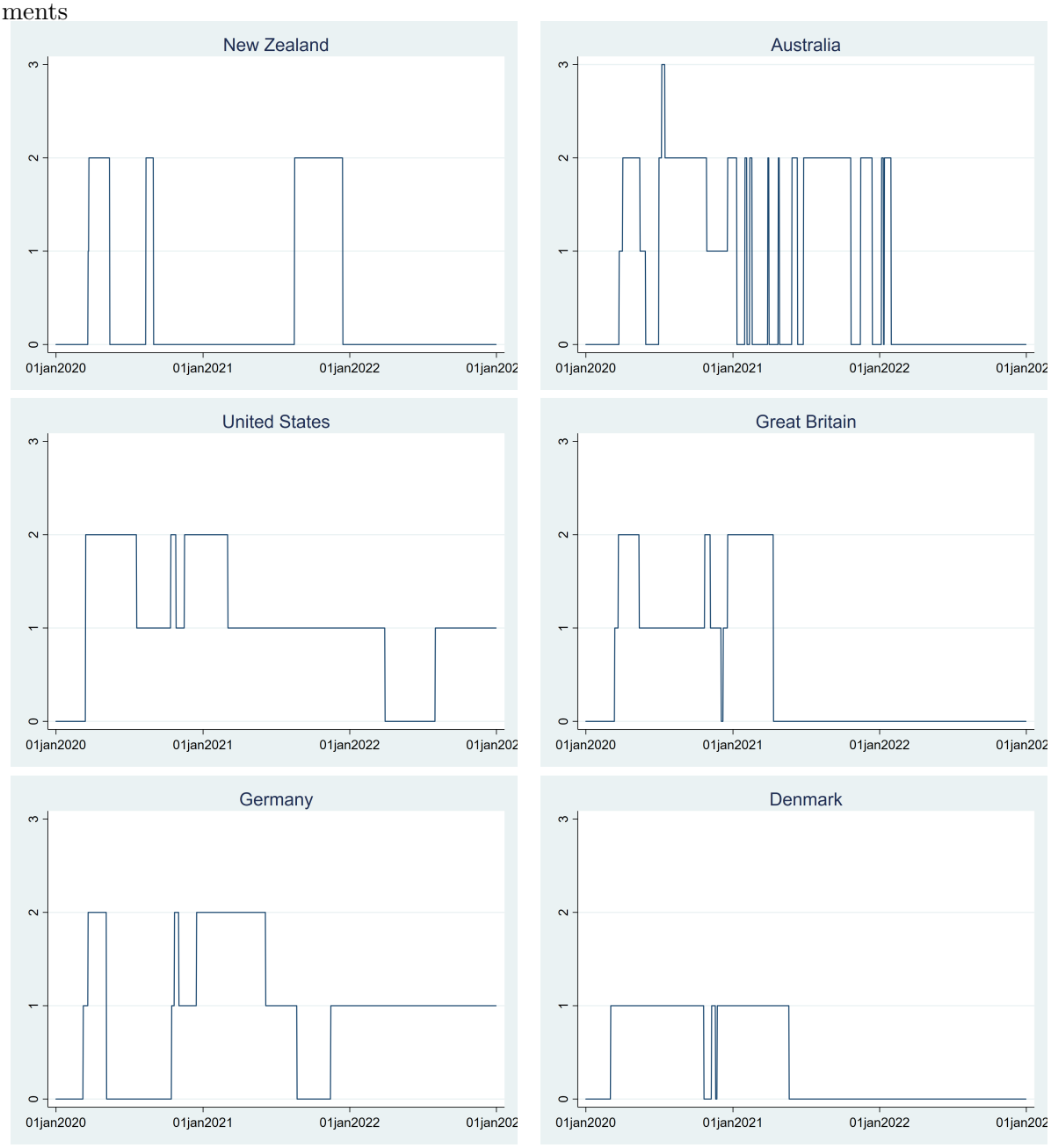
While evidence about the initial impacts of imposing social distancing restrictions seems to paint a picture of it causing falls in crime rates for some forms of crime, our understanding of what happens when those same restrictions are lifted is absent. Emerging tentative evidence from Mexico (Balmori de la Miyar et al. (2021); Vilalta et al. (2022)), the United States (Kim (2022); Riddell et al. (2022)), and Northern Island (Buil-Gil et al. (2021)) suggests that for some crimes at least there is a form bounceback or U-shaped recovery of criminal activity after COVID restrictions are relaxed. This tentative finding leads to more questions. Is the bounceback effect common across countries? Do crime rates bounce back to their original levels once movement and activity restrictions are relaxed or to lower or higher levels? How long does it take for any bounceback to occur? Do different types of crimes respond differently to relaxations of social restrictions? Apart from furthering our understanding of what drives criminal activity, knowing the answers to these sorts of questions gives policymakers more information about how to plan for and allocate resources to the criminal justice system in response to future disruptive events such as natural disasters or other pandemics.

New Zealand is an ideal candidate to study what happens when restrictions imposed to counter COVID-19 are removed. New Zealand went into a comprehensive national lockdown relatively quickly on 26 March 2020, less than a month from its first confirmed case on 28 February. The lockdown was nationally uniform and comprehensive in nature. New Zealand also came out of the full lockdown quickly on 28 April with most restrictions removed by 14 May. For most of New Zealand, since it came out of lockdown until recently, the lockdown was uninterrupted and in the very few instances when restrictions were reintroduced, they were not as severe, only for a selected part of the country, and only for short periods of time. In other words, New Zealand is about as clean a natural experiment for assessing the impacts of restrictions as can be found, as show in Figure 1. Furthermore, the New Zealand economy recovered quickly after the end of the original lockdown. The unemployment rate increased from 4.0% at the end of December in 2019 to 5.3% by September 2020, but fell back to 4.0% by June 2021. Real Gross Domestic Product per capita had fallen 13.3% from the end of December 2019 to the end of June 2020, but had almost fully recovered by March 2021.[1] The timelines of variables such as the unemployment rate and GDP in effect give us a natural experiment to study what happens to criminal activity with a temporary shock from lockdown restrictions and then their removal and with other aspects of people's lives returning to a state of near normality other than restrictions on international travel. This is as good an environment as exists in the world to study questions about the existence of any bounce back in criminal activity, and if any, the rate at which it bounces back by type of criminal offending.

In this paper we study the path of criminal activity in New Zealand from the initial lockdown to its removal and return to a state of life virtually the same except for the ability to travel internationally. We do this by comparing the time path of actual offending starting in July 2014 through to August 2022 against what would be predicted by a best fit ARIMA model under normal circumstances using the latest data on criminal offending in New Zealand. We do this for several cities, also for several categories of crime, and the novel feature of there being two identically restrictive lockdowns with a sizeable length and minimal restrictions between them. We find that most criminal activity in almost all of New Zealand fell statistically and economically during the lockdown but then bounced back to what would be predicted without the pandemic having occurred. This is true for both lockdowns. We also find that the impact is

[1]Nominal GDP had more than fully recovered by September 2020. Statistics mentioned are all from Stats NZ.

Figure 1: Oxford COVID-19 Government Response Tracker index C6: Stay at home requirements



smaller for the second lockdown with the reductions being smaller and the bounce-back occurring much more quickly. Additionally, the length of time of bounce-back is positively correlated with the initial size of the impact. A couple of possibilities for some of the results for specific crimes, are that responses to the pandemic and stay-at-home restrictions, such as increased use of working from home, or learning by potential offenders, affects subsequent impacts and bounce-back times.

2 Literature review

To the best of our knowledge there are no studies of the relationship between previous epidemics and crime before COVID-19 to guide what we would expect to occur in terms of removing mobility restrictions imposed in response to an epidemic. We can though predict what we would expect to observe using economic theories about criminal behaviour. The main framework for studying the economics of crime was developed by Becker (1968) and Ehrlich (1973). Their insight is that committing a criminal offence is a choice a person makes based on weighing up the expected benefits and costs from committing the offence. The expected benefits from offending are any monetary gains from it, any consumption benefits from illegal forms of goods or services, and any psychological or non-quantifiable utility benefits. The expected costs from the same offence are a function of the probability of the offence being detected, the probability of being successfully convicted and punished once detected, and the size of a direct cost of a fine or the opportunity cost arising from incarceration from successful prosecution. The latter cost can take the forms of foregone earnings or non-employment activities. This theoretical framework is also consistent with the routine activity theory from the criminal justice theories (Cohen and Felson (1979); Clarke and Cornish (1985)) that offending rates depend on the presence or absence of likely offenders (i.e. people who have a high expected benefit from committing an offence, that is, people with fewer positive returns from legal activities), suitable targets (i.e. the presence of high value premises or people or goods, or a higher expected benefit from committing an offence), and the absence of suitable guardians (i.e. a lower probability of being detected).

COVID-19 lockdown restrictions can affect both the costs and benefits from committing an offence. For example, the probability of being detected committing a domestic burglary would rise if most people are at home during a lockdown. This would imply that we can expect the number of these offences will fall since the expected cost of committing a domestic burglary

would have increased. On the other hand, we might not be certain about the sign of changes in commercial burglaries. A lockdown results in considerably less retail activity and therefore less cash and stock on-hand, reducing the expected benefit of robbing retail outlets. At the same time, because retail activity is severely curtailed, fewer people are present in commercial areas. If police attention is focused on enforcing lockdowns in residential areas and thus are mostly absent from commercial areas, lack of retail activity would cause a lower probability of being detected and expected cost of robbing a shop. A lower expected benefit combined with a lower expected cost means commercial burglaries could fall or rise in theory. One crime we could expect to rise during a lockdown would be domestic assaults. We know that lockdowns reduce economic activity. This results in fewer outside opportunities for partners living in the same household (Farmer and Tiefenthaler (1997); Tauchen et al. (1991)). One consequence is that it reduces the probability of a woman in a relationship reporting domestic assault during the lockdown, since they have a substantially reduced set of outside options such as alternative accommodation or support services. Another consequence is a lower likelihood of either partner leaving a household during a lockdown.

Both the economic theories and routine activity models of criminal behaviour tell us what impacts we can expect with lockdowns or stay-at-home orders resulting from COVID-19. Some forms of crimes will likely fall (e.g. residential burglaries or shoplifting), but some forms of crime will likely rise (e.g. domestic assaults or cyber-crime). Furthermore, these predictions appear to be increasingly supported by the studies on the impact of COVID based lockdowns to date. For example, Mohler et al. (2020) found statistically significant impacts of social distancing on some crimes in Los Angeles and Indianapolis, but with several differences between the two cities. Ashby (2020) examined the effects of various social distancing and stay-at-home orders from mid-January to early May 2020 on criminal offending in 16 large United States cities. He found that they were associated with no change in assaults (public or residential), decreases in vehicle theft and residential burglaries, and no change in non-residential burglary. Piquero et al. (2020) reported evidence of a short-term transient spike in domestic violence from stay-at-home orders in Dallas in the month after social distancing regulations came into effect. Studies in other countries have found similar impacts of COVID-19 lockdowns on crime. Halford et al. (2020) found that all recorded crime had fallen one week after lockdown in Lancashire in the United Kingdom for March 2020. They noted that lags occur from a crime being committed to reporting of the crime, and this likely contaminated their results for some forms of crime such

as domestic abuse and online fraud. Payne et al. (2021) found that common assault, serious assault, and sexual offending all fell significantly, the latter two statistically significantly, in the month after social distancing regulations came into effect. Payne and Morgan (2020) found significantly lower rates were reported for shop and other thefts and credit card fraud for the Australian state of Queensland during March 2020. Reported rates of other crimes showed no statistical impact from the restrictions. The study by Nivette et al. (2021) assessed the impacts of lockdown-style restrictions on criminal activity in 27 cities across 23 countries rather than focusing on a single city or country. The data is daily, from May to September of 2020 with the time period of a specific country depending on the data's most recent availability at time of publication. They find that stay-at-home restrictions were associated with an average fall in offending of 37% across all cities; those with stricter restrictions experienced larger falls on average. Patterns differed across cities and types of crime, for example some cities experienced increases in burglary. The weakest result is for homicide. This would be expected particularly for those countries with high levels of organised crime, since organised crime would, by its nature, be relatively unresponsive to a stay-at-home order.

While there seems to be a growing pool of evidence about the initial impacts of the lockdowns and stay-at-home orders resulting from COVID-19, less is known about the longer-term effects of these policies: both about what happens if stay-at-home restrictions are used for long periods of time and what happens after they are removed. Nivette et al. did find some evidence suggesting that crime rates started increasing once the stay-at-home restrictions ended, but this wasn't the focus of their study. Similarly, Wang et al. (2021) in a study focusing on the impact of social distancing on criminal activity in New South Wales showed that lockdowns led to significant declines in criminal activity, but as the lockdown continued, there seemed to be a tentative possibility of a rebound effect. Borrion et al. (2020) focused on developing a resilience based framework to measure and analyse the full time period impact of a disruptive event, in this case COVID-19. Their case study was the impact of COVID and associated lockdown on commercial theft in one Chinese city up to the end of April 2020. As part of this work they did find a clear bounce-back effect after the lockdown-based restrictions were removed. One recent piece of evidence is from two Mexican studies focusing on the removal of restrictions. Balmori de la Miyar et al. (2021) find that Mexican crime rates do bounce back to their original levels by roughly seven months after Mexican lockdown measures were relaxed. Hoehn-Velasco

et al. (2021) find this basic pattern also but focusing on crimes specifically against women in Mexico with the bounce back being roughly three to four months after relaxation of the social restrictions. A differently located study is that of Buil-Gil et al. (2021), who find that criminal activity in general fell during the multiple lockdowns or stay-at-home orders in Northern Ireland but then subsequently bounced back to pre-pandemic levels. The exception was cybercrime, which rose during the lockdowns and then remained higher than before the lockdowns.

While providing valuable suggestive evidence of the effects of removing social distancing, the few currently available studies have obvious problems when used to determine the dynamic behaviour of crime rates from removing stay-at-home restrictions. An obvious problem with these studies is the limited time after the relaxation of social distancing restrictions studied, making it difficult to judge whether possible bounce-back effects occur, their sizes, how long they take, and if they are pertinent to all or only some types of crimes. Another issue arises from some using only the crime rate values immediately before a lockdown as a naive measure of the counter-factual comparison level. A further issue arises for some studies if the cities or countries involved experience messy sequences of changing stay-at-home restrictions. This contaminates the study of their removal. The case of New Zealand is, however, more informative for studying these dynamic effects of removing lockdowns. We have a long sample horizon of 28 months of data for six crime types in six New Zealand cities. The lockdowns in New Zealand were comprehensive and clean. We also use the ARIMA technique to take into account the seasonal, trend and other features of the crime data to produce a more sophisticated measure of expected future crime rates as points of comparison. The additional interesting aspect to our study is that there were two identical lockdowns, with 14 months between the end of the first and the start of the second and 11 months from the end of the second lockdown. This allows us to compare the effects of a novel first lockdown and a subsequent significantly later lockdown.

3 COVID-19 in New Zealand

The first confirmed New Zealand case of COVID-19 was on 28 February 2020. As case numbers rose, the New Zealand government implemented stricter restrictions on social mixing. Some forms of gatherings of more than 500 people were banned on 16 March, then indoor events of more than 100 people were banned on 19 March. The border was closed to most foreigners on 20 March. On the next day, 21 March, the government introduced a four tiered Alert

system. New Zealand started at Level 2, which restricted the sizes of gatherings and people allowed in a shared space, with an emphasis on social distancing and the ability to trace people's interactions.[2] The stricter Level 3 emphasising mixing of related and small 'bubbles' of people known to each other was invoked two days later on 23 March, and a total lockdown (Level 4) for most people and most activities was implemented soon on 26 March. This rapid introduction of private and social restrictions represents, as Stickle and Felson (2020a) describe, the largest criminological experiment in history. A notable feature of social distancing in New Zealand is that the changes were introduced quickly: within ten days the entire country had moved from normal free movement to a total lockdown for most of the population. The social distancing restrictions were reflected in the large falls in mobility of the population while in effect. Locations such as retail and recreation, parks, and transit stations, saw mobility fall by about 50% from February to May 2020, according to Google mobility data. In Auckland, mobility fell by about 40% from August to September 2021 in retail and recreational locations. Also notable was the high level of compliance with Ministry of Justice statistics showing only 641 prosecutions by the end of 2021 for violating social distancing restrictions, of whom 463 were convicted, out of a population of approximately 5.1 million.[3] The result of these factors was the very low number of infections over the period social distancing restrictions were in place with daily new infections mostly in single digits up until mid-August 2021, with many days with no new reported cases.

While social distancing was effective in limiting transmission of Covid-19, there were obvious economic repercussions. Some occupations, such as those in the supermarket, health, or transport industries were classified as essential and exempt from the social distancing restrictions. Other industries and occupations adapted to working from home more easily than others, such as office workers and educational services. Some industries though relied on physical proximity of consumers to services, such as tourism and hospitality, or production technology that depended on the physical presence of employees, such as manufacturing and construction. Given that about 60% of employed people in New Zealand could not work from home during lockdown, unemployment could have risen considerably under social distancing restrictions.[4] This did hap-

[2]The specific conditions of New Zealand's Level system can be found at `https://covid19.govt.nz/alert-system/covid-19-alert-system/`.

[3]While overall compliance was high, there is tentative evidence that compliance rates were lower for certain groups, such as youth (Broodryk and Robinson (2022).

[4]Stats NZ: `https://www.stats.govt.nz/news/four-in-10-employed-new-zealanders-work-from-home-`

Table 1: New Zealand COVID-19 Alert Levels

Alert Level	COVID Status	Transmission	Measures in Place
1	Sporadic isolated cases	Low	QR scanning Masks on public transport
2	A few active clusters	Limited	QR scanning, masks, distancing Mask wearing & distancing for retail, public transport, hospitality etc Mask wearing & distancing for public-facing employment Group size limitations for hospitality, events, funerals etc Education & health care on site
3	Multiple active clusters	Medium	QR scanning, masks, distancing Most businesses click & collect only Travel permitted for essentials Maximum of 10 at Weddings & funerals Work from home except where can't & can distance Public facilities & most education closed
4	Widespread multiple outbreaks	Sustained	Lockdown Only essential travel permitted Only essential retail open Work from home except essential services

Source: New Zealand Government, `https://covid19.govt.nz/about-our-covid-19-response/history-of-the-covid-19-alert-system/\#alert-levels`

pen initially with Fletcher et al. (2022) finding in a stratified survey of New Zealanders that by three weeks after the social distancing restriction policy was introduced, 6% of those employed pre-lockdown lost their jobs due to the lockdown. They were predominately in retail, wholesale, hospitality, manufacturing, and construction. Two-thirds of surveyed workers employed in these industries also experienced lower incomes due to reduced hours of work or lost employment.

In response to the possibility of large increases in unemployment, the New Zealand government implemented an expansionary fiscal policy resulting in a sizeable deficit and growing government debt. A large amount of extra government spending was used to fund a national employment subsidy policy package to support employment and moderate the negative impact of lockdown on employment. For example, as soon as an employer's revenue over 30 days was at least 30% lower compared to a similar period the previous year, the government would pay the employer a subsidy of almost 58% of pre-tax median weekly earnings (Maani (2021)). The take-up rate as a percentage of 2019 dependent employees was estimated to be about 60% (Andrews et al. (2021)). This policy was also continued through to the second national lockdown

`during-lockdown`

starting on 17 August 2021. The labour wage subsidy policy also supported the government's desired wider aim of maintaining economic activity. Romer (2021) shows that the New Zealand fiscal policy stance was highly expansionary. By the end of July 2020, New Zealand's expansionary fiscal policy package as a percentage of GDP was roughly equal to that of the United States as the highest among 30 OECD countries. The central bank simultaneously responded to the pandemic by lowering its central bank funds rate from 1% immediately before Covid-19 to 0.25% two months later. It remained at this level through to September 2021, after which it was gradually increased. It also engaged in large scale asset purchases, expanding the monetary base by 209% over this period, leading to an increase of 65.7% in M1.[5]

The expansionary fiscal and monetary policies meant that there was relatively little change in unemployment over the social distancing period as mentioned earlier. It reached a high of 5.3% by the end of September 2020 but then progressively fell until it reached a low of 3.2% by December 2021. The employment rate was similarly stable: it was 72.5% before Covid-19 (2019 Q4) and 73% by the end of the lockdown period (2022 Q2).[6] Furthermore, while nominal GDP fell by 1.1% over the March 2020 quarter and a further 10.4% over the June 2020 quarter, it had more than recovered by the end of the December quarter. Retail sales followed a similar pattern although with larger falls but recovering sooner. This reflects the pattern of changes in population mobility in retail and recreational locations. Interestingly, population mobility in retail and recreational locations took four months to recover after the first lockdown in March-May 2020, but only one month after the second nationwide lockdown in August-October 2021.[7] The faster return to 'business-as-usual' possibly reflects New Zealanders' feeling more comfortable living with the COVID virus and any consequences it might have for individuals. The speed with which New Zealanders' mobility and the wider economy recovered from lockdowns suggests that any enduring differences between criminal offending rates before and after the lockdowns predominately stems from changes in underlying behaviours than due to economic considerations associated with the lockdowns.

[5]Statistics from the Reserve Bank of New Zealand. The monetary base is made up of currency held by the public and settlement cash balances, or commercial bank reserves at the central bank.

[6]Stats NZ: `https://www.stats.govt.nz/indicators/employment-rate/`

[7]Google mobility data

4 Data and estimation

Victimisation time and place data come from the New Zealand Police.[8] Each observation is a crime record, which is assigned an ANZSOC (Australia and New Zealand Standard Offence Classification) subdivision code and a location type. We aggregate some of these subdivisions together by location type (residential vs. non-residential) to produce six crime categories that are comparable to those typically used by comparable studies in other countries. These six crime categories are (with average percentage of records in parentheses): 1, serious assault in public (10%); 2, serious assault in residences (1%); 3, residential burglaries (24%); 4, non-residential burglaries (40%); 5, theft of vehicles (11%); 6, theft from vehicles (11%). Together, these six categories account for about 97% of all crime records. In terms of cities, we focus on the six most populous in New Zealand, from largest to smallest: Auckland (population: 1.6 million), Christchurch, Wellington, Hamilton, Tauranga, Dunedin (population: 129 thousand). Thus, we will study 36 time series: six crime types from each of the six cities. The police dataset also contains other variables such as the occurrence day-of-week and hour-of-day, any weapons used, and the number of victims for each record; we do not make use of these variables in this study.

The number of crimes per month differs widely across crime types: fewest reported cases in serious assaults in residences, and most cases in non-residential burglaries. Serious assaults in residences show a general upward trend throughout our eight year sample period in all cities except Dunedin. Residential burglaries seem to go through more obvious cycles in some cities than other crime types. However, cycles from different cities do not align; neither do they have the same length. Most relevant to our analysis is its apparent increase since mid-2019 till the arrival of the pandemic. This can be seen in all cities in our sample except Dunedin. Non-residential burglaries show a similar spike: all cities except Wellington and Dunedin experience an unprecedented sharp increase in the few months before the start of the pandemic. As a result, the forecast crime rates during the pandemic are much higher than pre-COVID levels. This pattern is seen in all our sampled cities, except the smallest one, Dunedin. The theft of vehicles have been on a mildly increasing trend in four out of six cities; it is relatively flat in Auckland and Wellington. The theft from vehicles show some obvious peaks and troughs, but they are not aligned across cities. Overall, the data suggest that different crime categories have

[8] `https://www.police.govt.nz/about-us/publications-statistics/data-and-statistics/policedatanz/victimisation-time-and-place`.

different underlying mechanisms, which also possibly differ across cities. Thus, the estimation of the effect of the pandemic on crime will be more robust when compared across multiple cities.

We use five and a half years of monthly pre-COVID data, up to February 2020 (marked by a vertical gray line in all graphs), to estimate a seasonal ARIMA model for each crime category in each of the six cities. We first perform an automatic order selection procedure using pre-COVID data for each time series. The results can be found in table 4. Eight out of 36 selected models have a 12-month seasonal component (indicated by non-zero values in parameters P, D, Q), with four of these time series located in Auckland. Among the six crime types, serious assault in public (figure 3) is the one that is most often found to have a 12-month seasonality component. Exactly half of the selected models contain a non-zero autoregressive parameter (p). Slightly more than half (21 out of 36) of the selected models have a non-zero moving-average (q) parameter. Lastly, two-thirds (24 out of 36) of the selected models have a non-zero number of difference (d).

After order selection, we estimate the selected (seasonal) ARIMA models to produce dynamic forecasts, from March 2020 to August 2022. In all graphs that follow, the solid line shows each model's fitted values pre-COVID (up to February 2020) and the dynamic forecast post-COVID (starting March 2020). The dynamic forecasts form the counterfactual of our analysis. The counterfactual for each crime category city case is the crime numbers that would evolve under the same econometric models in the absence of COVID-19, at least for a short period of time before a new shock to the model arrives.

We show the actual and fitted time series for all six crime types in the appendix. In all graphs, we use a dashed gray line to denote the actual crime numbers, and a solid black line for the fitted crime numbers in the pre-COVID period (before March 2020) and dynamically projected crime numbers during the pandemic (starting March 2020). We also shade the 95% confidence interval computed from the mean squared error of the predicted values. We use red markers to denote the monthly observations where the three lockdowns take place: red circles for the first nationwide lockdown in March, April, and May 2020; a red triangle for the Auckland-only lockdown in August 2020 (marked on graphs for Auckland only); red squares for the second nationwide lockdown in August, September, and October 2021 for Auckland and Hamilton, August and September 2021 only for the remaining four cities.

5 Results

In the this section we look at three things: (1) the initial or short-term impact from imposing lockdowns; (2) the dynamic or longer-term impact from removing lockdowns; and (3) differences across types of crimes. Our long time series allows us to observe the response of crime rates after each of the three lockdown episodes. We can observe whether and in how much time actual crime rates return to pre-COVID levels, forecast levels, or its 95% confidence interval. We can also observe whether the pandemic causes a break in the long-term crime patterns. The presence of multiple lockdowns, at various alert levels (3 and 4), within the same cities allow us to conduct within-city comparisons, in addition to the between-city comparisons we have mentioned above. As part of studying the dynamic impact we will tabulate the time for crime rates to 'bounce back', defined as the return of actual crime rates to projected levels after a lockdown episode.

In addition to comparing the counterfactual and actual crime numbers in graphs, we also present their differences in table 2. It details the direction and magnitude in the change of crime rate during each of the two nationwide lockdowns, for each crime type and city. We calculate the percentage change in crime rate as the projected crime rate minus the observed crime rate, for each monthly observation during that lockdown episode. Since there are two or three monthly observations for each lockdown episode, we record the largest percentage decrease (or the smallest percentage increase) in the table. We do not compute a simple average between the monthly observed differences because the lockdowns did not take up the entirety of their first and last calendar months.

In the same table 2 we also present the time required for each crime rate to return to projected levels after each lockdown. Since the vast majority of these changes are decreases (the two instances of increase are statistically insignificant, as noted above), we will henceforth refer to the 'return' of crime rates to projected levels as 'bounce backs'. Note that 'bounce back' is *not* defined as the return of crime rates to pre-COVID levels; our choice of definition is identical to that used in the criminal science literature. In table 2, the time to bounce back is expressed in number of months in square brackets ([]) underneath each change. Zero means that the observed crime rate has already bounced back *during* that lockdown period. A cross ($\times$) indicates that observed crime rates have not bounced back within the time frame of our study, where the last observation is August 2022.

Table 2: Percentage change in crime rate during lockdowns, and the number of months it takes to return to post-lockdown

	Auckland	Christchurch	Wellington	Hamilton	Tauranga	Dunedin
March-May 2020 nationwide lockdown						
Serious assaults in public	−52.27*	−42.94*	−70.82*	−38.32*	−66.11*	−54.19*
	[1]	[1]	[1]	[2]	[2]	[1]
Serious assaults in residences	−54.77*	−66.74	−81.50*	−17.55	−37.41	−38.89
	[5]	[2]	[2]	[2]	[0]	[3]
Residential Burglaries	−45.91*	−43.99*	−36.78*	−50.13*	−47.19*	−43.01*
	[20]	×	[24]	[4]	[8]	[5]
Non-residential Burglaries	−68.98*	−64.13*	−77.81*	−69.90*	−80.67*	−67.37*
	[27]	[24]	[25]	[10]	×	[3]
Theft of vehicles	−68.00*	−57.65*	−67.34*	−70.69*	−72.78*	−31.14
	[8]	[23]	[4]	[13]	[7]	[7]
Theft from vehicles	−76.05*	−75.83*	−78.70*	−67.28*	−56.64*	−74.77
	[12]	[8]	[24]	[5]	[6]	[5]
August 2020 Auckland-only lockdown						
Serious assaults in public	−10.38	29.42*	13.02	20.37	9.260	12.87
	[2]	[0]	[0]	[0]	[0]	[0]
Serious assaults in residences	−13.45	17.95	−10.26	29.12	21.92	86.10
	[2]	[0]	[2]	[0]	[0]	[0]
Residential Burglaries	−25.94*	−33.42*	−28.77*	−11.79	−20.94	−16.41
	[17]	×	[21]	[1]	[5]	[2]
Non-residential Burglaries	−32.34*	−11.58*	−13.20	−11.67	−24.85*	6.050
	[24]	[17]	[21]	[7]	×	[0]
Theft of vehicles	−16.32	−40.15*	−1.927	−39.98*	−24.34	−49.56*
	[5]	[20]	[1]	[10]	[4]	[4]
Theft from vehicles	−27.03*	−19.12	−33.64	−17.42	−39.83*	−41.33
	[9]	[5]	[21]	[2]	[3]	[2]
August-September/October 2021 nationwide lockdown[1]						
Serious assaults in public	−29.44*	−14.96	−34.50*	−24.32*	−53.84*	−10.12
	[1]	[0]	[2]	[1]	[2]	[0]
Serious assaults in residences	−36.76*	−12.79	−52.70	−31.33	−24.63	131.1
	[0]	[1]	[2]	[0]	[0]	[0]
Residential Burglaries	−15.87*	−37.01*	−41.91*	−7.369	−33.96*	−59.88*
	[3]	×	[7]	[2]	[0]	[1]
Non-residential Burglaries	−47.61*	−26.77*	−35.99*	−31.98*	−65.07*	−2.108
	[10]	[7]	[7]	[4]	×	[0]
Theft of vehicles	−5.201	−61.23*	−6.363	−34.69*	−37.30*	−21.25
	[0]	[6]	[0]	[0]	[0]	[0]
Theft from vehicles	−47.42*	−16.18	−52.86*	−14.75	−58.33*	2.943
	[7]	[0]	[7]	[0]	[1]	[0]

[1] This lockdown ended in October in Auckland and Hamilton City, and September for all other cities.

Notes: Size of change in crime rate is given by the most negative (or least positive) percentage change of the monthly observations during the respective lockdown period. Each percentage change is the difference between the observed and forecast crime rates of the same month. Statistically significant changes are indicated by *. 'Return' is defined as the first post-lockdown monthly observation where the observed crime rate exceeds the projected crime rate by the estimated ARIMA model. The number of months from the end of lockdown to return to the projected rate is given in square brackets []. A cross (×) indicates that there was no return to projected rates after that lockdown episode within the time frame of our dataset.

Initial effects from lockdowns

General findings

Firstly, we note that the changes in criminal offending is striking in the first nationwide lockdown that spans March, April, and May 2020. Actual crime rates fell markedly cross almost all crime types and cities, with 30 of the 36 possible crime-city impacts statistically significant. Percentage changes against forecast crime rates for all 36 crime-city cases were negative in the March-May 2020 nationwide lockdown. Similarly, all but two changes among the 36 were negative in the second nationwide lockdown in August-October 2021. However, these decreases in the second nationwide lockdown were smaller in magnitude than the first, and 15 of the 36 crime-city cases were statistically insignificant. This suggests the presence of some dynamic changes once the first lockdown was lifted. In general, even a year after the end of the first lockdown, crime levels had not returned to the pre-COVID levels, so any fall in the second lockdown was in general noticeably less pronounced.

In August 2020, Auckland spent 18 days under alert level 3, two months after the end of the first nationwide lockdown, while the rest of New Zealand were at alert level 2, with much fewer mobility restrictions. This provides a valuable natural experiment for cross-city contemporaneous comparisons. This local lockdown was shorter and less stringent compared with the other two nationwide lockdowns. Within Auckland, the local lockdown brought a decrease in only serious assault in public and non-residential burglaries compared with the previous month. The decrease in serious assaults in public is not statistically significant. In crime types where the August 2020 observation is significantly lower than forecast, it is a continuation of consecutive observations falling statistically below forecast since the March-May nationwide lockdown, which happened only three months prior. Thus, it is possible that the August 2020 observation was still under the influence of a dynamic effect from the first nationwide lockdown. This may be the reason why the numbers of some crime types in other cities also fell significantly below forecast as they had much fewer restrictions in place.

Secondly, the majority of the changes are statistically significant; certainly, all significant changes are negative for lockdown instances. In the March-May 2020 lockdown, only one sixth of changes in the 36 cases are insignificant; these concentrate in one crime type (serious assaults in residences) and city (Dunedin, the smallest in our sample). In the August-October 2021 lockdown, just more than half of the changes in the 36 cases are significant. There is the same

concentration of insignificant changes in the same crime type (serious assaults in residences) and same city (Dunedin). In the August 2020 Auckland-only lockdown, half of the Auckland observations are statistically significant. In the other other five cities, the majority of the changes are insignificant.

Thirdly, the percentage changes are larger in magnitude in the March-May 2020 lockdown than the August-October 2021 lockdown for most of the 36 cases. Within Auckland, the changes in the August 2020 Auckland-only lockdown have the smallest percentages compared with those in the other two nationwide lockdowns. In addition, when we compare across cities in each crime type in a lockdown, we often observe that larger cities experience larger impacts. This was most prominent in the March-May 2020 lockdown.

A simple explanation for the more significantly negative impacts in the first nationwide lockdown compared to the second lockdown is because the former includes more days under alert level 4 (the highest alert level with the strongest restrictions) than the latter. It could also be a by-product of the forecasts potentially being more reliable for the first lockdown. Since the counterfactual crime rates for both lockdowns are formed using pre-COVID data (up to February 2020), the first March-May 2020 lockdown is much closer in time to the pre-COVID data than the second August-October 2021 lockdown. The difference between the actual and counterfactual crime rates will capture the impact of the lockdown only when all other factors affecting crime are held constant between the 'before' and 'after' periods. This assumption weakens with the passage of time. Since the August-October 2021 lockdown takes place 1.5 years after our pre-COVID data, its counterfactual may possibly be a less meaningful reference point.

The strong pattern that emerges from our New Zealand data is in broad agreement with the economic theory of crime. The majority of April 2020 falls within the alert level 4 lockdown period, with the last few days of April and the first half of May under alert level 3. For crime types that take place in residential locations, more people stayed home during the lockdown (we know this from mobility data), increasing the likelihood of being caught red-handed, which is a key factor determining the marginal costs of engaging in criminal activity. For crime types that take place in public, the drastic decrease in activity in public spaces during the lockdown (we also know this from mobility data) draws more attention to a criminal than an otherwise busy environment. This also increases the likelihood of being caught. Furthermore, with less

commercial activity and fewer people and vehicles in public, the pecuniary gains from robbery or burglary fall. Comparing the March-May 2020 lockdown against the August-October 2021 lockdown, longer and stricter restrictions in April 2020 is associated with a larger decrease in crime, relative to the counterfactual.

Property crime

Both the theft of vehicles and the theft from vehicles experienced significant falls in the March-May 2020 nationwide lockdown. The exception was Dunedin where neither kind of theft had a statistically significant decrease. This likely reflects that Dunedin in preceding years had relatively few vehicle-related thefts compared to the other cities and it was on a downward trend. The falls in crimes are between -31% and -73% for theft of vehicles and between -57% and -79% for theft of vehicles. The lockdown effects in New Zealand are of the same order of magnitude as those in other countries, and relatively larger in size. For example, Abrams (2021) reports an impact of a 2% rise in theft of vehicles and a more modest fall of theft from vehicles of -20.3% for the US. Nivette et al. (2021) find a fall of -39% for theft of vehicles for 27 international cities. It is difficult to compare across other studies due to a lack of consistency of crime definitions, but Balmori de la Miyar et al. (2021) reports a fall of -16.8% in theft and property crime for Mexico and Langton et al. (2021) finds a fall of -50% for other theft for England and Wales. These are bigger than impacts found in other studies. In contrast, half of the decreases of theft involving vehicles in New Zealand are insignificant in the August-October 2021 nationwide lockdown. In the August 2020 Auckland-only lockdown, only the theft from vehicles in Auckland experienced a significant fall. Surprisingly, there are four other instances of significant falls in other cities.

Both residential and non-residential burglaries fell significantly in all six cities in the March-May 2020 nationwide lockdown. The maximum percentage difference from the ARIMA forecasts based on historical patterns from the first lockdown was between -37% to -50% for residential burglaries and -64% to -81% for non-residential burglaries. These are comparable with Nivette et al.'s meta-analysis estimate of an average fall in burglary of 28% internationally, Abrams' finding of a fall of 23.5% in residential burglaries and an increase of 37.9% in non-residential burglaries for the US, Langton's estimate of a fall of 33% for burglaries in England and Wales, and 16.8% fall in theft and property crime in Mexico by Balmori et al. The sizes of falls of

burglaries in New Zealand were unsurprising given mobility fell sharply, reducing the presence of people in non-residential areas, and increasing the percentage of those employed who worked from home.[9]

The same impact is seen in the August-October 2021 nationwide lockdown as well, with the exceptions that the falls were noticeably smaller, and two out of twelve instances were insignificant (residential burglaries in Hamilton and non-residential burglaries in Dunedin). Both of these instances occurred in the three smaller cities in our sample. Within each of these two lockdowns, non-residential burglaries always experienced a larger decrease than residential burglaries. In the August 2020 Auckland-only lockdown, both kinds of burglaries fell significantly in Auckland. Surprisingly, they also fell significantly in Christchurch, as well as one instance each in Wellington and Tauranga.

Serious assaults

There was a statistically significant decrease in serious assaults in public across all six cities in the March-May 2020 nationwide lockdown, the maximum percentage difference from the ARIMA forecasts being between -38% to -71%. Serious assaults in residences showed a smaller decrease than those in public in all six cities. Residential assaults declined from -18% to -82%; they were generally statistically insignificant, although large in percentage terms. This is unsurprising given that they were from a considerably much lower base than other forms of crime. These are comparable with Nivette et al.'s meta-analysis estimate of an average fall in all assaults (domestic and public) of 35% internationally, Abrams' finding of a fall of 17.3% in domestic violence for the US, Langton's estimate of a fall of 24% for all forms of violence and sexual offences burglaries in England and Wales, and a 24% fall in all forms of assault and battery in Mexico by Balmori et al. Finally, as mentioned earlier and as argued by Abrams for the US, the figures for reported domestic-based violence during the lockdowns almost certainly underestimated the actual rate of domestic violence. Furthermore, if public violence is falling because fewer people are spending time outside the home, it would be logical that domestic violence should increase if people are

[9]Stats NZ began surveying the location of work as part of its Household Labour Force Survey with the first cohort surveyed for the June 2020 quarter. Unfortunately this means we are not able to compare this directly with the pre-COVID situation. But we can compare indirectly: after the lockdowns ended, those working from home fell over time. In addition, the number of people who report that they otherwise do not usually work from home was considerably higher during the lockdowns than afterwards.

spending more time in the home, during a time of stress.

Compared to the first lockdown, the August-October 2021 lockdown in contrast brought a smaller decrease to each of the cities in serious assaults. These decreases are equally insignificant in the second nationwide lockdown; only the largest city, Auckland, experienced a significant fall. In the August 2020 Auckland-only lockdown, neither type of assault had a statistically significant fall in Auckland. However, surprisingly, serious assaults in public had a significant *increase* in Christchurch. Overall, serious assaults in residences is the crime type that is the least affected by the lockdowns.

Dynamic responses after removing each lockdown

The focus of almost all studies has been the initial effects of stay-at-home restrictions on criminal activity. However, there is the question of what happens once these restrictions are removed. As we have argued, New Zealand is a highly informative case to address this issue. Given the length of time studied, we have a sufficient time span to determine the dynamic effects of removing lockdowns for most crimes and for most cities, with the additional advantage of being able to do this twice with the two nationwide lockdowns. Our first important finding is that crime levels eventually returned to what would normally be expected (based on the ARIMA forecasts). If we exclude Auckland, for the five cities that had a lockdown 14 months after the first, 23 of the 30 crime-city cases had returned to the normal levels after the first lockdown. The noticeable exceptions of not returning to normal by the start of the second lockdown were residential and non-residential burglaries in Wellington and Christchurch. This might possibly be a result of continuing unusually high levels of working from home relative to the other three cities. For instance, Wellington is the capital with a relatively high proportion of professional workers who could easily work from home. Of these 30 crime-city cases, 28 of the 30 returned to normal levels after the second lockdown. Furthermore, including Auckland, 34 of the 36 crime-city cases eventually returned to their normal levels, with residential burglaries in Christchurch and non-residential burglaries in Tauranga the two in each lockdown that did not return to their normal levels. For most crimes in most cities, the return to normal levels occurs within a month after the second lockdown.

Our second finding relates to what happens with multiple lockdowns. Excluding Auckland due to its having a separate city-only lockdown, we have a sufficient gap in time to deduce

the dynamic impact of a second identical lockdown following a first one. We find that it takes less time to bounce back from a subsequent lockdown, at least in the time span we study. Considering 30 crime-city combinations, the median time to return to expected levels was five months after the first national lockdown but only one month after the second. This would seem a result of a generally smaller economic impact from the second lockdown on the number of crimes being committed. It could also potentially be capturing a dynamic behavioral response of potential offenders to lockdowns. The first lockdown is novel and potential offenders face a high degree of uncertainty about the probability of being caught. By the second lockdown, any potential criminal offender knows more about how lockdowns work and can have devised methods of offending better designed to lower the probability of being caught when most people are confined to their residences or are essential workers (e.g. hospital or supermarket employees) travelling between their residences and workplaces.

Our third finding is that overall there is a moderate negative correlation of -0.56 between effect size and bounce back. In other words, instances of a bigger decrease in crime rate are associated with a longer time period till the crime rate recovers to projected levels. Figure 2 is a scatter plot of all values from table 2 (excluding the six instances where the crime rate did not recover to projected values within the time frame of our data set). The calculated correlation remains similar — a moderate negative value — when we consider each lockdown or each city individually. Instances where crime rates take no time to bounce back are naturally most likely to be found where the effect size is insignificant.

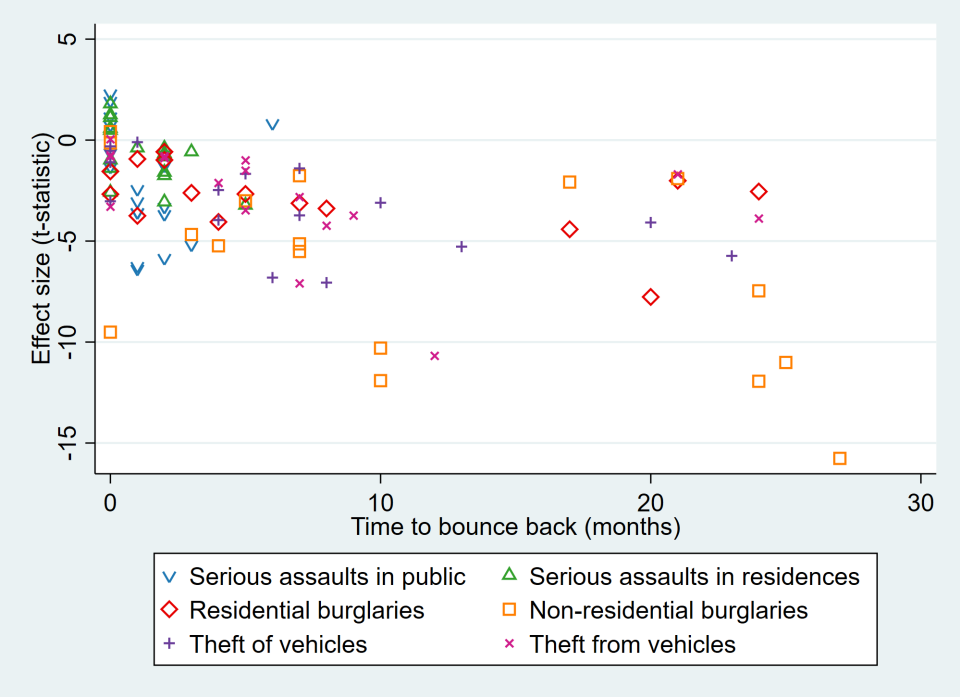


Figure 2: Scatter plot between effect size and bounce back time

Related to our third finding is that there is a distinct difference in time to bounce back between crime types and cities. Serious assaults, both in public and in residences, took a very short time, generally a couple of months, to bounce back in almost all instances. This is true in both lockdowns in five cities and all three lockdowns in Auckland. Assaults also have the weakest negative correlation (-0.29) between effect size and time to bounce back, from the 36 instances across the three lockdowns. Property crime types took longer and showed more variance between cities. The three smaller cities mostly see both kinds of vehicle thefts bounce back in around half a year or less, while the three biggest cities experienced instances of longer bounce back, taking around two years. The theft of vehicles in Christchurch and the theft from vehicles in Wellington took two years to bounce back after the March-May 2020 nationwide lockdown. In the August-October 2021 nationwide lockdown, this crime category took no more than seven months to bounce back across all cities.

The pattern for vehicle theft shares similarities with that of burglaries. Both residential and non-residential burglaries took around two years to bounce back in the three biggest cities in the March-May 2020 nationwide lockdown. Furthermore, once burglary crime rates had fallen after the first nationwide lockdown, they had not returned to the projected levels when the

second lockdown occurred for five of the cities, and for Auckland after its third lockdown came about. Residential and non-residential burglaries showed the strongest contrasts in bounce back times between largest and smaller cities. Bounce back was much faster, taking under a year, for the three smaller cities in the March-May 2020 nationwide lockdown and for all cities in the August-October 2021 nationwide lockdown. The correlation between effect size and time to bounce back is -0.52, from the 36 instances across the three lockdowns. As mentioned, this might be a function of the extent to which a workforce is working from home, which would depend of the distribution of industries and occupations in a city. In contrast, we do not observe an obvious contrast in effect size between crime types and cities.

It is difficult to compare our findings to the few other studies that mention what happens after stay-at-home restrictions. Nivette et al. and Buil-Gil et al. both report signs of bounceback effects. The problem with Nivette et al. is their counterfactual is the average crime rate across their 27 cities for each crime just before the restrictions were imposed. This is not a reasonable forecast of expected 'normal' crime rates over time. The issue with Buil-Gil et al. is that there are multiple lockdowns of different degrees of restrictions and there is limited time between them to allow the dynamics to play out. Balmori de la Miyar et al. (2021) does calculate a more sophisticated counterfactual forecast of crime rates, but it has a maximum seven months only to assess the dynamic responses of crime rates to the removal of stay-at-home restrictions. They do find that different crimes subsequently rebound, and within two months homicide has returned to its pre-pandemic level with fraud taking three months to do so. But, theft and property crimes, assault and battery, and petty drug crime and extortion were still below pre-pandemic levels, while trending back to them.

6 Discussion

Some differences in impacts on crime rate between New Zealand and countries such as the US likely reflect the fact that New Zealand's lockdowns were nationalwide and implemented quickly with only a small window from their announcement and initiation of public restrictions. The lockdowns were also the extreme form of stay-at-home restriction and the available evidence is that they were effectively policed and obeyed, resulting in significantly decreased mobility everywhere (Cheung and Gunby (2022)). The differences relating to car thefts and non-residential burglaries reflect cross-country differences between the US and New Zealand. It is also consis-

tent with the results of Nivette et al. that stricter forms of stay-at-home restrictions resulted in larger falls in crime, the exception being homicide. These findings are consistent with those in New Zealand. The difference in impact of restrictions on residential assaults in New Zealand, equivalent to Abrams' domestic violence, is possibly due to greater under-reporting in the US relative to New Zealand, with domestic violence known to be an under-reported crime.

There is a clear difference in our finding of a large decrease for non-residential burglaries compared to, say, Abrams, who reported a large increase. It is possible that non-residential burglaries committed under lockdown in New Zealand could have been under-reported due to business owners' absence, but this seems unlikely for the following reasons. As previously mentioned, the available evidence is that the lockdowns seemed to have been widely effective. The dates in our crime statistics are those when the offense is reported or becomes known to the police. If the police knew about the non-residential burglaries from burglar alarms or remote access of CCTV camera footage by business owners at the time the crimes occurred, then they would be reflected in crime statistics during the lockdown. If instead the non-residential burglaries were reported after the lockdowns, it should spike above forecast. While the actual data do increase after the lockdowns ended, the increases were occurring before the end of the lockdowns and are still well below expected levels in the first month after each lockdown ended. Furthermore, there is no mention or evidence of unusual reporting of commercial burglaries after the end of lockdowns in annual reports of major insurance companies or statistics of the national industry body (the Insurance Council of New Zealand.) Instead the focus is on large claims on business interruption insurance. Finally, the non-residential burglary falls could potentially reflect under-reporting, which seems unlikely given these would mainly be commercial premises and insurance claims require reporting of the associated crimes to the police. Further, while not covering non-residential property, the annual New Zealand Crimes and Victims Survey report a stable reporting rate from 2018 through to the end of 2021 of approximately 25%.[10] This is suggestive that the fall in non-residential burglaries is likely not due to under-reporting.

One issue with our findings for assault in residences is possible under-reporting of domestic violence, as suggested by Abrams, Ashby, and Hoehn-Velasco et al. If a victim is forced to reside with their offender due to the lockdown, then they could be less likely to report domestic

[10]The NZVCS is an annual random stratified survey by New Zealand Police of 8,000 New Zealanders on their experiences with crime, with a response rate of between 76% to 80%. See `https://www.justice.govt.nz/justice-sector-policy/research-data/nzcvs/resources-and-results/`.

violence for fear of increasing the amount and severity they experience. Domestic violence is under-reported in New Zealand with the NZCVS finding that only between 6% to 8% of sexual assaults are reported. Furthermore, the survey reports that victims' fears of reprisals or making things worse as a reason for not reporting regarding interpersonal assaults rose from 12% at the end of 2019 to 23% by the end of 2020, the period that includes the first lockdown. This suggests that domestic violence during the lockdowns was likely under-reported and casts doubt on the lockdowns causing falls in serious assaults in residences. The falls were generally statistically insignificant and normally considerably smaller in number than other forms of crime anyway. They also likely overstated the true effect, as argued in other studies.

With respect to the initial impact of the New Zealand lockdowns, the impacts were similar in direction to other international studies by types of crime. The difference was that the reduction in criminal offending were typically substantially stronger in New Zealand than elsewhere. This is because New Zealand had a successfully enforced strict national stay-at-home restriction. The difference between Abrams (increase for the US) and New Zealand (decrease) regarding non-residential burglaries likely reflects this feature of the stay-at-home restriction in New Zealand. Where New Zealand stood out is having a second additional lockdown with the same restrictions, a significant gap between the two, and with effectively no restrictions between them other than the closing of the international border. What eventuated was a similarly sized initial impact but the impact for a far shorter length of time. This then leads to the dynamic effects where there is limited international evidence. The New Zealand experience provides a much clearer picture of how a lockdown plays out and provides valuable information about the possibility of bounce-back effects and their features. For most crime types, the reductions in offending rates bounce back to the normal expected levels once the lockdowns are removed. Furthermore, additional lockdowns have a smaller impact on crime rates and a significantly shorter period of impact. One interesting implication and potential cause of these two outcomes is the possibility that potential offenders learn from prior stay-at-home restrictions on how to modify their offending to offset the increased chances of getting caught from the restrictions.

7 Conclusion

The wide-spread imposition of social distancing restrictions in response to the Covid-19 pandemic was, as characterised by Stickle and Felson (2020b), the largest criminological experiment

in history. Evidence to date clearly supports their description. As we show in this paper, restrictions are associated with significant falls in some categories of crime, reinforcing the results of other studies. But, as we also show as part of the novelty of this paper, repeated use of social restrictions, with gaps between their use, appear to cause smaller subsequent falls in criminal activity. The obvious question is: why? An interesting speculative explanation is that potential criminals learn how to offset, at least to some extent and for some crimes, the positive impact of social restrictions on the probability of being caught. The second and highly novel aspect of this paper regards the dynamic pattern in criminal activity after the lifting of the social distancing restrictions. As we show, there is evidence of a bounceback effect for almost all types of crime, although the speed of the bounceback varies considerably by type of crime, with faster returns to counterfactual rates of activity for violent crime and slower returns for forms of property crime. An additional novel finding is that the rate of bounceback is faster for a subsequent lockdown. Again, one possibility for it is that potential criminals learn how to adapt to the changes in people's social and economic behaviour with the removal of social distancing restrictions. Our findings, apart from filling in major gaps that currently exist about what happens when restrictions are removed, have important implications for policing and resourcing of law enforcement. We show that reductions in crime are not likely to be permanent and the subsequent restrictions are likely to have less impact on criminal offending. As such, the initial impact of social distancing restrictions is not a reason for lowering resources for law enforcement or the criminal justice system, nor for people in general to reduce steps they take to secure their property and themselves from criminal activity.

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A Appendix

Table 3: Time of Major COVID-19 Events in New Zealand

Date	Alert Level	Event
Feb 28, 2020	-	First report COVID-19 case.
Mar 14, 2020	-	Incoming travellers to self-isolate for 14 days.
Mar 19, 2020	-	Borders closed except to citizens and permanent residents.
Mar 21, 2020	2	Alert Level introduced.
Mar 23, 2020	3	Announcement of move to level 4 in 48 hours.
Mar 25, 2020	4	State of National Emergency declared.
Mar 29, 2020	4	First COVID-19 death reported.
Apr 20, 2020	4	Announcement of move to level 3 in 5 days.
Apr 27, 2020	3	Move to level 3.
May 13, 2020	2	Expiry of State of National Emergency.
Jun 8, 2020	1	Announced that were no active cases of COVID.
Aug 11, 2020	1	4 new community cases announced.
Aug 12, 2020	2	Auckland to level 3.
Aug 30, 2020	2	Auckland moves to level 2.
Sep 21, 2020	1	Auckland stays at level 2.
Oct 7, 2020	1	Auckland moves to level 1.
Feb 14, 2021	2	3 new community cases announced, Auckland to level 3.
Feb 17, 2021	1	Auckland to level 2.
Feb 22, 2021	1	Auckland moves to level 1.
Mar 7, 2021	1	Auckland moves to level 2.
Mar 12, 2021	1	Auckland moves to level 1.
Jun 23, 2021	1	Wellington moves to level 2.
Jun 29, 2021	1	Wellington moves to level 1.
Aug 17, 2021	4	New Zealand moves to level 4.
Aug 31, 2021	3	Auckland & Northland stay at level 4.
Sep 2, 2021	3	Auckland stays at level 4.
Sep 7, 2021	2	Auckland stays at level 4.
Sep 23, 2021	2	Auckland moves to level 3.
Oct 3, 2021	2	Hamilton & Waikato area also move to level 3.
Oct 8, 2021	2	Northland also moves to level 3.
Oct 19, 2021	2	Northland moves to level 2.
Nov 11, 2021	2	Northland moves to level 2.
Nov 16, 2021	2	Some of Waikato area moves to level 2.
Dec 2, 2021	2	End of Alert Level system.

Source: New Zealand Government, `https://covid19.govt.nz/about-our-covid-19-response/history-of-the-covid-19-alert-system/#timeline-of-key-events`

Table 4: Seasonal ARIMA Model Order Selection Results

City	Crime category	p	d	q	P	D	Q	MASE
Auckland	1 serious assault in public	2	0	0	1	0	0	0.793
Auckland	2 serious assault in residences	0	1	1	0	0	0	0.696
Auckland	3 residential burglaries	1	0	1	0	0	1	0.708
Auckland	4 non-residential burglaries	1	1	0	1	0	1	0.787
Auckland	5 theft of vehicles	1	0	0	0	0	0	0.752
Auckland	6 theft from vehicles	0	1	0	1	0	0	0.722
Christchurch	1 serious assault in public	2	0	0	0	0	1	0.821
Christchurch	2 serious assault in residences	0	1	1	0	0	0	0.827
Christchurch	3 residential burglaries	2	1	2	0	0	0	0.898
Christchurch	4 non-residential burglaries	0	1	4	0	0	0	0.868
Christchurch	5 theft of vehicles	0	1	1	0	0	0	0.769
Christchurch	6 theft from vehicles	1	0	0	0	0	0	0.864
Dunedin	1 serious assault in public	0	0	0	0	0	1	0.829
Dunedin	2 serious assault in residences	1	0	0	0	0	0	0.836
Dunedin	3 residential burglaries	5	0	0	0	0	0	0.724
Dunedin	4 non-residential burglaries	0	0	1	0	0	0	0.860
Dunedin	5 theft of vehicles	3	1	0	0	0	0	0.852
Dunedin	6 theft from vehicles	0	1	1	0	0	0	0.799
Hamilton	1 serious assault in public	0	1	1	0	0	0	0.816
Hamilton	2 serious assault in residences	0	1	1	0	0	0	0.732
Hamilton	3 residential burglaries	1	0	2	0	0	0	0.788
Hamilton	4 non-residential burglaries	1	1	0	0	0	0	0.906
Hamilton	5 theft of vehicles	0	1	1	0	0	0	0.955
Hamilton	6 theft from vehicles	1	0	0	0	0	0	0.916
Tauranga	1 serious assault in public	2	1	1	1	0	0	0.852
Tauranga	2 serious assault in residences	0	1	3	0	0	0	0.831
Tauranga	3 residential burglaries	1	1	1	0	0	0	0.710
Tauranga	4 non-residential burglaries	0	1	1	1	0	0	0.834
Tauranga	5 theft of vehicles	1	1	1	0	0	0	0.896
Tauranga	6 theft from vehicles	0	1	1	0	0	0	0.758
Wellington	1 serious assault in public	0	1	1	0	0	0	0.849
Wellington	2 serious assault in residences	0	1	1	0	0	0	0.984
Wellington	3 residential burglaries	4	1	0	0	0	0	0.847
Wellington	4 non-residential burglaries	0	1	1	0	0	0	0.892
Wellington	5 theft of vehicles	3	0	0	0	0	0	0.853
Wellington	6 theft from vehicles	3	1	0	0	0	0	0.956

Figure 3: Number of series assaults in public in six New Zealand cities

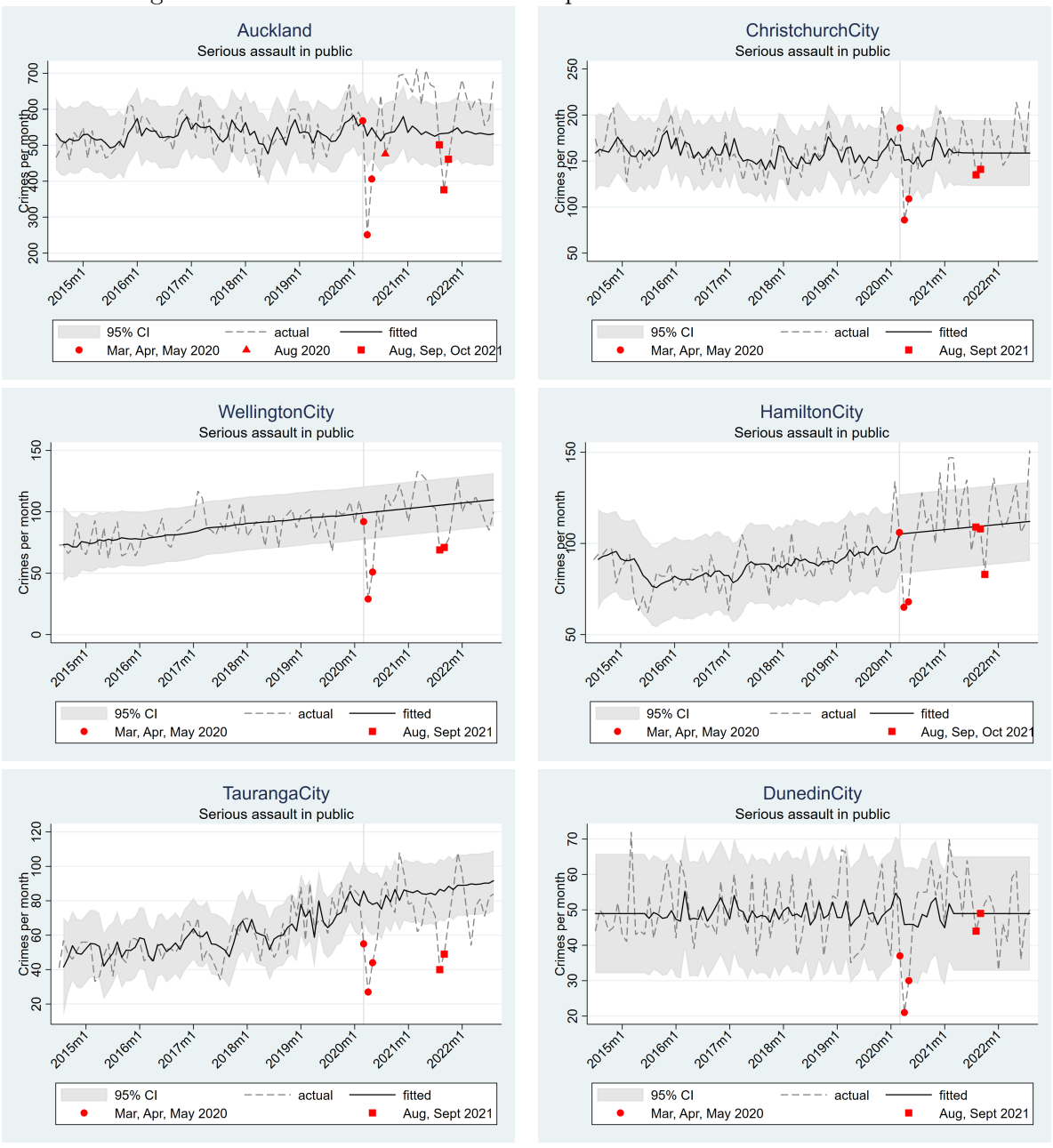

Figure 4: Number of serious assaults in residences in six New Zealand cities

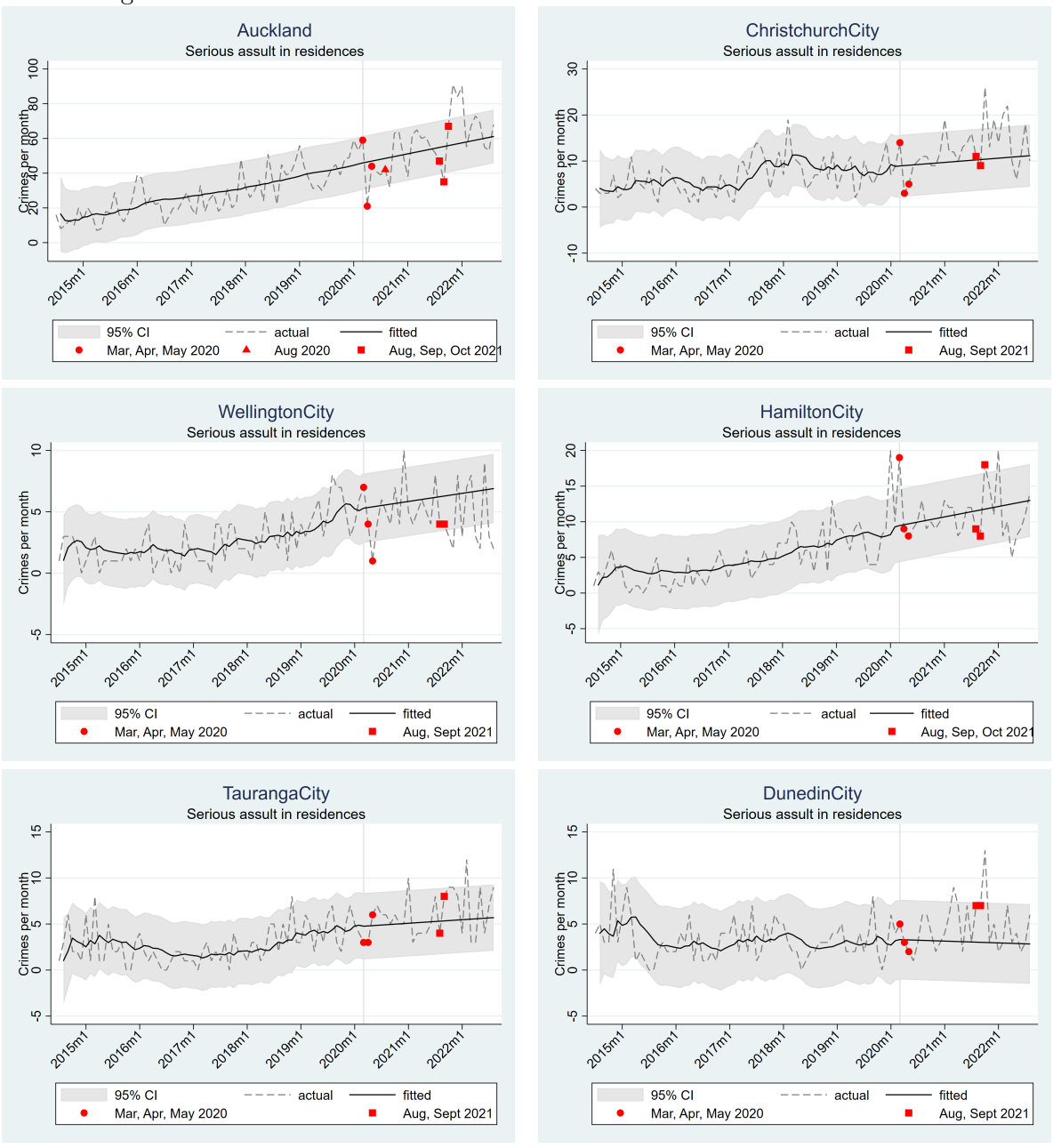

Figure 5: Number of residential burglaries in six New Zealand cities

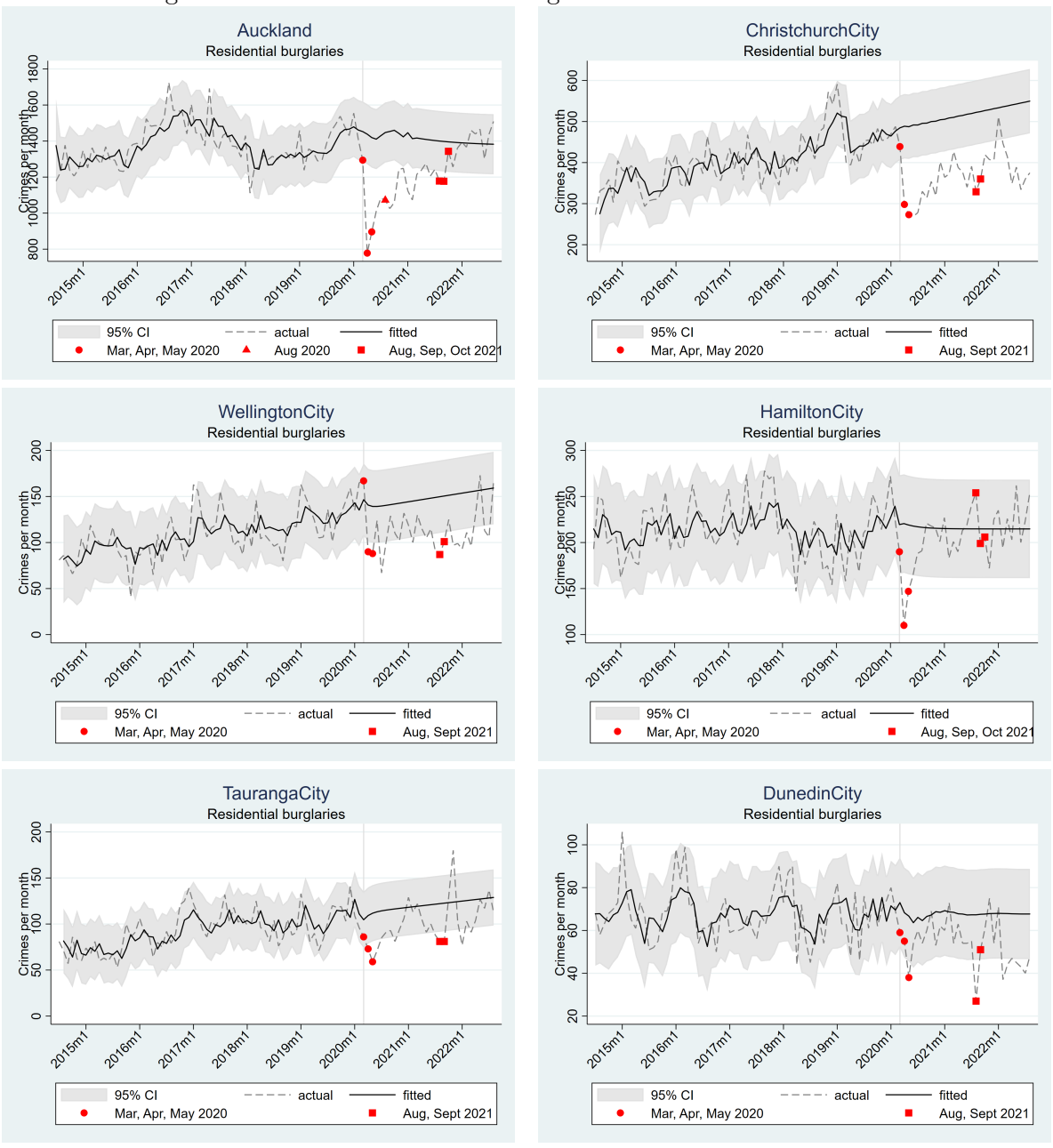

Figure 6: Number of non-residential burglaries in six New Zealand cities

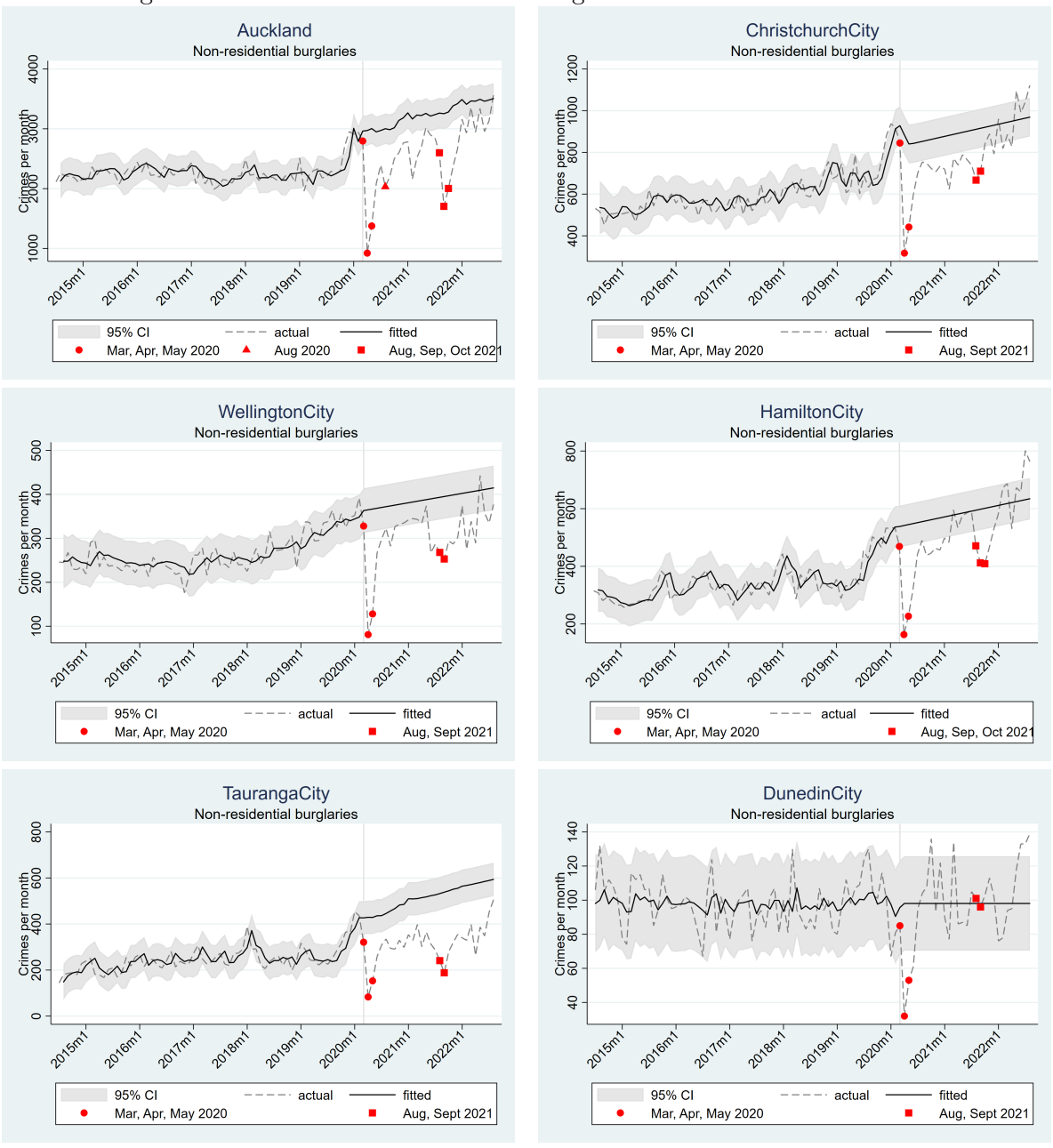

Figure 7: Number of thefts of vehicles in six New Zealand cities

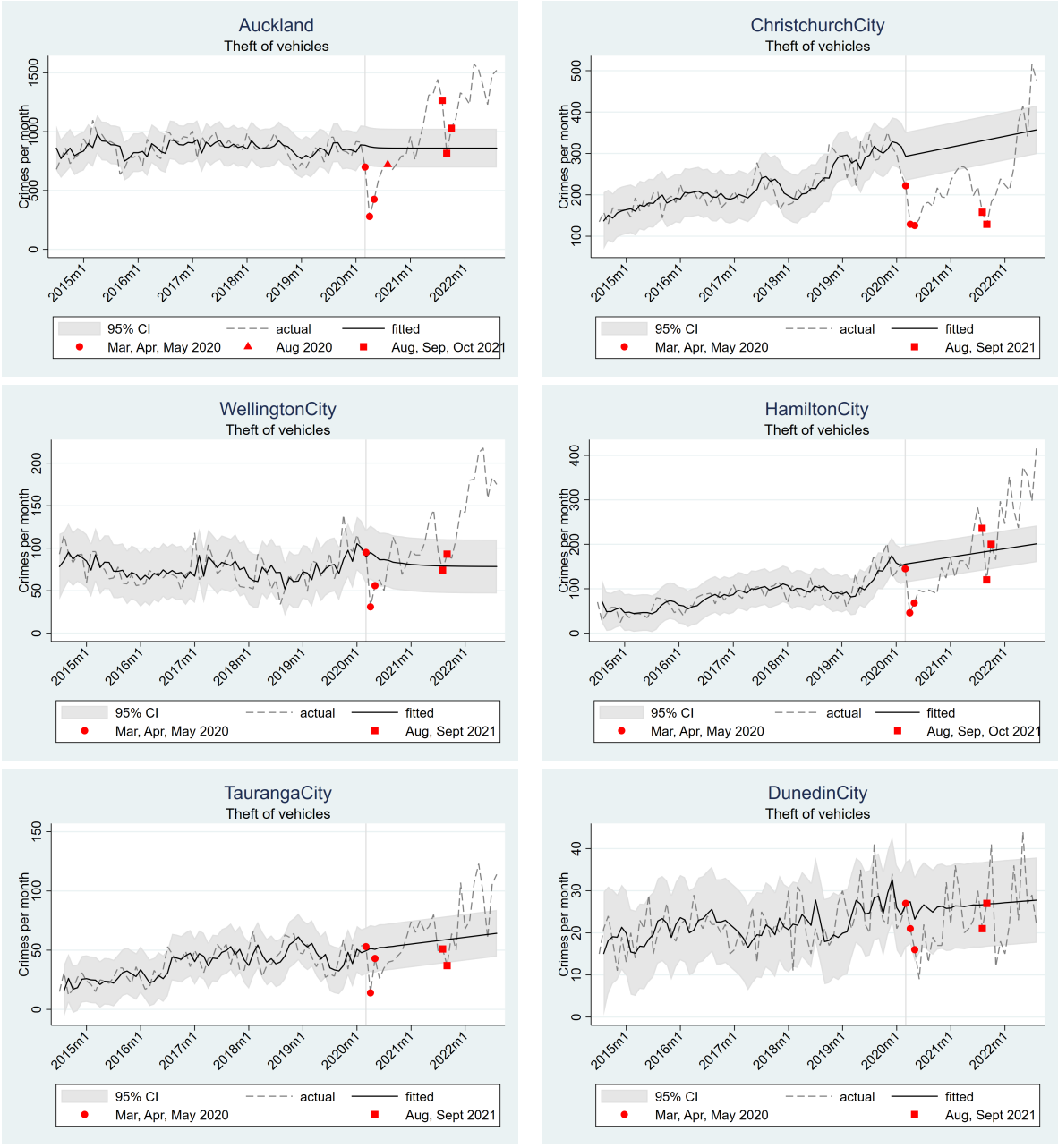

Figure 8: Number of thefts from vehicles in six New Zealand cities