

UNIVERSITY OF WAIKATO

**Hamilton
New Zealand**

**The Rollout of COVID-19 Booster Vaccines is Associated
With Rising Excess Mortality in New Zealand**

John Gibson

Working Paper in Economics 11/22

June 2022

John Gibson

School of Accounting, Finance
and Economics
University of Waikato
Private Bag 3105
Hamilton, 3240
New Zealand

Tel: +64 (7) 838 4289

Email: jkgibson@waikato.ac.nz

Abstract

The rollout of booster doses of COVID-19 vaccines to the general population is controversial. The ratio of vaccine risk to benefits likely has swung more towards risk than during the original randomized trials, due to dose-dependent adverse events and to fixation of immune responses on a variant no longer circulating, yet the evidence underpinning mass use of boosters is weaker than was the evidence for the original vaccine rollout. In light of an unsatisfactory risk-evidence situation, aggregate weekly data on excess mortality in New Zealand are used here to study the impacts of rolling out booster doses. Instrumental variables estimates using a plausible source of exogenous variation in the rate of booster dose rollout indicate 16 excess deaths per 100,000 booster doses, totaling over 400 excess deaths from New Zealand's booster rollout to date. The value of statistical life of these excess deaths is over \$1.6 billion. The age groups most likely to use boosters had 7–10 percentage point rises in excess mortality rates as boosters were rolled out while the age group that is mostly too young for boosters saw no rise in excess mortality.

Keywords

COVID-19

excess mortality

instrumental variables

vaccines

New Zealand

JEL Classification

D61

I18

I. Introduction

The rollout of booster doses of COVID-19 vaccines to the general population has been controversial in many countries. In September 2021 an advisory panel of outside experts to the US Food and Drug Administration (FDA) voted 16-2 against widespread use of these boosters due to lack of safety data and doubts about benefits of mass boosting over targeted approaches (Perrone and Neergaard, 2021). After this vote was ignored and the FDA approved boosters for the general population the top two officials in FDA's Office of Vaccines Research and Review resigned and criticized decision-making about mass rollout of boosters (Krause et al, 2021). This critique noted that if unnecessary boosting causes significant adverse reactions it may increase vaccine hesitancy more generally; a concern raised elsewhere that the potentially low benefits of COVID-19 vaccines relative to the costs borne by vaccinees (such as exposure to breakthrough infections and to vaccine adverse events) may undermine public confidence in other vaccination efforts (Godlee, 2020; Gibson, 2022a). Even the World Health Organization argue that a vaccination strategy based on repeated booster doses of the original vaccine composition is unlikely to be appropriate or sustainable (WHO, 2022).

Notwithstanding these concerns, many countries began booster rollouts in the second half of 2021, and to date (mid-June, 2022), 2.1 billion booster doses have been given, compared with 10 billion original protocol doses. These are especially a feature of rich countries, where boosters have been one-quarter of all doses given versus just 3% of doses administered in low-income countries (Mathieu et al, 2021). Aggregate data for one set of rich countries (the OECD members) show higher excess mortality when more booster doses are used.¹ This accords with higher all-cause mortality amongst vaccinees in Pfizer's original randomized trial (Gibson, 2022b)—recalling that booster doses are just the original Pfizer/BioNTech BNT162b2 recipe. Moreover, if vaccine adverse events are dose-dependent, and if using a booster formulated for the original Wuhan strain of SARS-CoV-2 fixates the immune system to protect against a variant no longer circulating (Reynolds et al, 2022), the ratio of vaccine risks to benefits swings more towards risks than at the time of the original randomized trials. Hence, there are calls to relax coercive vaccine policies (Bardosh et al, 2022) and as a safety measure for further booster vaccinations to be discontinued (Yamamoto, 2022). Several European countries have already restricted some mRNA vaccines to only those aged over 30 years due to these safety concerns.

Given this shift in the risk-benefit ratio, stronger evidence should underpin mass use of boosters but in fact the opposite holds; even with caveats about limited scope of the original trials (Doshi, 2020) and lack of access to their raw data (Doshi et al, 2022) at least the original vaccine rollout waited for large-scale trials yet booster rollouts (and their extension to younger age groups) often rely on far weaker, observational, studies. These observational studies may be biased by assuming selection on observables, by miscategorising treatment groups (and the treatment periods), and by under-estimating the (residual) numbers unvaccinated causing their COVID-19 rates to be exaggerated (Neil et al, 2022). This gradual erosion of evidence-based

¹ Appendix A shows that monthly average excess mortality p-scores (the percentage by which total deaths differ from expected deaths) are 4.4 percentage points higher for every 10 doses per 100 people higher is the average booster rate (the mean booster rate is 28 per 100), for 31 OECD countries between August 2021 and May 2022.

medicine, to instead be inverted as medicine-based evidence, is exemplified in a remark made by Dr Eric Rubin, editor-in-chief of the *New England Journal of Medicine*, when participating in an FDA advisory panel that voted to give emergency use authorization to Pfizer's BNT162b2 vaccine for 5-11 year old children:

“We’re never going to learn about how safe this vaccine is unless we start giving it. That’s just the way it goes. That’s how we found out about rare complications of other vaccines...”

(FDA, 2021, p.312)

In light of debates about mass rollout of booster doses of COVID-19 vaccines, evidence is provided here on the association between booster rollout and rising excess mortality in New Zealand. Time-series analysis of aggregate data is often considered a weaker form of evidence but the sort of studies usually thought to give stronger evidence, like large randomized control trials (RCTs), are either not being done for boosters (Makary, 2022) or have various biases that likely inflate apparent vaccine efficacy (Gibson, 2022b). Moreover, aspects of the current study help bring it closer to the experimental ideal. First, New Zealand persisted with zero-COVID for longer than most countries other than China, allowing effects of higher doses to be studied free from other (confounding) effects. Most people in New Zealand who received the original two doses of Pfizer and then the booster had no prior exposure to SARS-CoV-2. For example, only by late February 2022 did cumulative cases of COVID-19 in New Zealand exceed 1% of the population.² By then, 8.2 million original protocol Pfizer doses and 2.2 million booster doses had been administered. In other words, about half of the population were both ‘fully vaccinated’ and ‘boosted’ prior to having any experience of COVID-19.

A second strength of the study is to exploit a plausible source of exogenous variation, with an instrumental variables (IV) strategy, so associations between booster rollout and excess mortality can be interpreted not just as correlations but also in quasi-experimental causal terms. The results suggest 16 (95% CI: 5 to 27) excess deaths per 100,000 booster doses, amounting to over 400 excess deaths in New Zealand given the booster doses administered to date. If this rate of excess deaths is extrapolated to other countries, it amounts to over 300,000 excess deaths worldwide. The rise in excess mortality since the booster rollout began occurs in all age groups except the youngest (under age 30), who mostly are ineligible for boosters. In economic terms, if an age-adjusted value of statistical life of \$4 million is applied, excess mortality associated with New Zealand’s booster rollout is valued at over \$1.6 billion.³ Even just one percent of this value of lost life (\$16 million) would have been more than sufficient to carefully study booster impacts by randomizing the rollout and could also have funded surveys of vaccine adverse events rather than relying on the current passive reporting system. Instead, local health authorities seemed to outsource decisions to industry-captured overseas regulators.

² Using cumulative cases per million people from *Our World in Data*. Omicron arrived on 26 January 2022. Earlier variants were suppressed by using two-week managed isolation and quarantine for overseas arrivals, quarantining community cases and their household contacts, and a series of hard lockdowns.

³ Cost-benefit analyses by the NZ Treasury reportedly use a Value of Statistical Life (VSL) of \$4.7 million (Coughlan, 2019) which is about \$5m in 2022 terms. Age-adjustment is needed because no booster-related rise in excess mortality shows up for the 0-29 age group. Using a quality-adjusted life year value of \$62,000 (Lally, 2021) adds up to almost \$1 million for the median person aged 0-29 years, so without them the average VSL for the remaining ages should be about \$4 million.

II. Excess Mortality Estimates

Estimates of excess mortality for a particular era require the expected number of deaths per period (weekly, in this case). The means from a prior era are often used. For example, Kung et al (2021) compare week-specific mean death rates from 2015-19 to death rates in 2020 when arguing that there were no apparent adverse effects of lockdowns on mortality in New Zealand. Expected deaths can also be calculated from regressions, letting factors that change over time be incorporated (using means ignores such changes). A regression approach is used here:

$$Deaths_{jt} = \alpha_0 + \gamma_j + \rho T_t + \delta ResPop_{jt} + \varphi Shocks_{jt} + \varepsilon_{jt} \quad (1)$$

where j indexes weeks and t years, the γ_j are fixed effects for each week of the year, the time index T (=1 for 2011, 2 for 2012 and so on) allows for secular trends (such as from rising life expectancy), the resident population ($ResPop$) controls for any increase in deaths due to a larger population, and the vector of shocks is for mass death events not expected to reoccur.

There are three notable features of equation (1). The full span of data from the start of 2011 is used because it is inefficient to discard part of a time-series.⁴ Death rates are not used because their denominator depends on population projections for the latest years (Németh et al, 2021), which are inexact for New Zealand due to migration-induced fluctuations in population. Instead, quarterly population estimates are a control variable, and in conjunction with the time-trend allow dynamic forecasting of expected deaths into the booster era. Third, parameters are estimated through to the end of March 2020 (and then used to predict on an April-to-March year basis). This timing reflects New Zealand's late response to COVID-19 (Gibson, 2022c), as major interventions (lockdowns and MIQ) did not affect weekly deaths before April 2020, covers the vaccine rollout period (<1% of doses were prior to April 2021), and allows for the slow reporting of deaths such that reliable figures end in April 2022.⁵

Results of equation (1) are given in Appendix B, for all-ages and for the four age-groups specified in the deaths data: 0-29 years, 30-59 years, 60-79 years, and 80 years plus. In seasonal patterns, all-ages deaths peak in week 32 (late July), with 153 more (95% CI: 125 to 181) than in week 7 (mid-February) that has fewest deaths. There are more deaths as population increases but fewer over time holding population constant. The two shocks (Christchurch earthquake and mosque shooting) are precisely ($p < 0.02$) estimated to purge their effects from the predictions (that is, these shocks are modelled as non-recurrent).

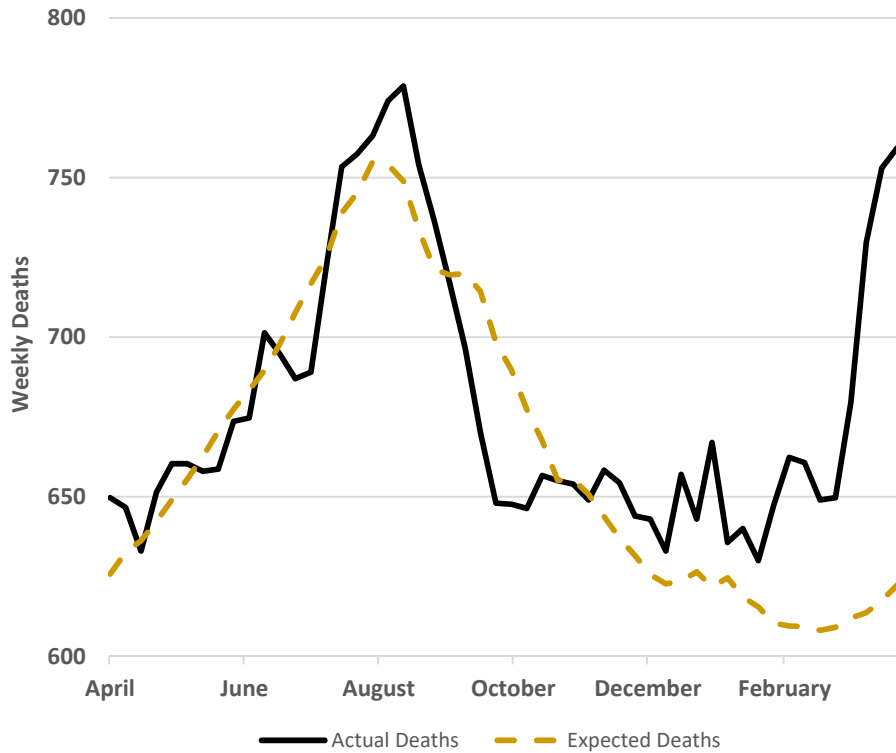
Weekly all-cause, all-ages, deaths are shown in panel A of Figure 1, as a 3-week moving average (so based on the week ahead, the week behind, and the current week). This slight smoothing lets patterns be seen clearly without distraction from very short-term volatility. In addition to actual deaths for 2021-22, the expected number of deaths each week are also shown, based on the regression analysis discussed above. Expected deaths rise linearly from mid-February to the end of July, then decline with some unevenness through to December, fluctuate a little and then reach their annual low of 610 per week in mid-February.

⁴ Data are from <https://www.stats.govt.nz/experimental/covid-19-data-portal>. Counts of all deaths (for four age groups), based on week of death, are given. This is more correct than using date of registration (which is based on burial or cremation dates).

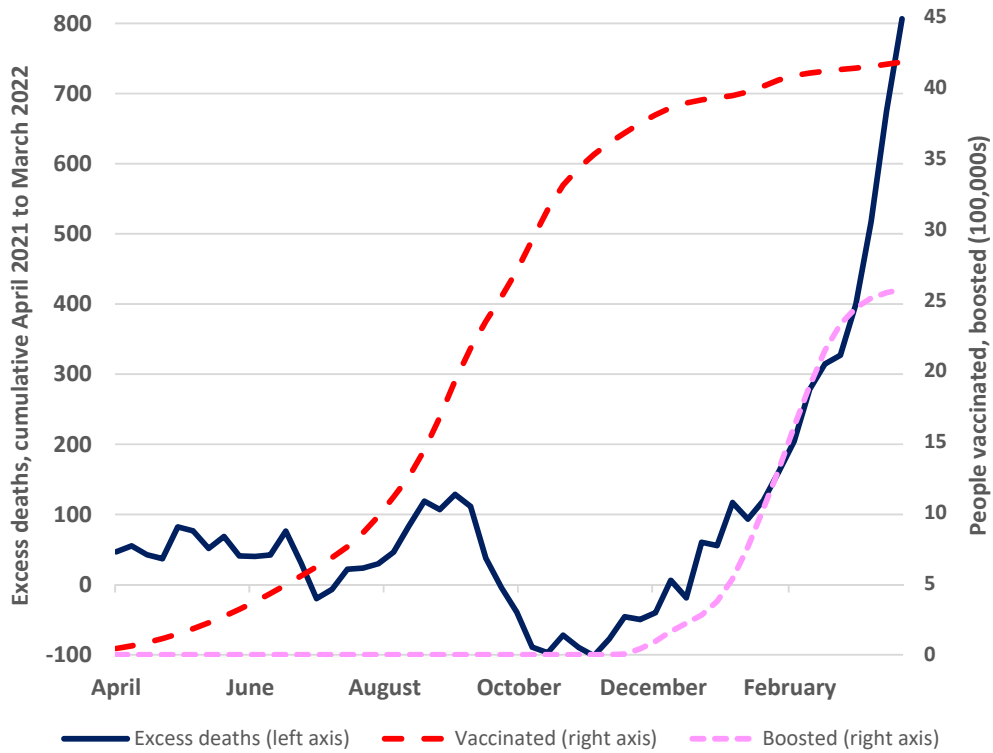
⁵ As of mid-June 2022, deaths data are available through late May. However, latest counts are revised upwards for several weeks thereafter so the most accurate data have a lag of at least eight weeks.

Figure 1: Excess Mortality and COVID-19 Vaccine Rollout in New Zealand

A) Actual and Expected Deaths (Weekly Moving Averages): April 2021 to March 2022



B) Cumulative Excess Deaths and COVID-19 Vaccine Rollout: April 2021 to March 2022



Actual deaths largely followed the pattern of expected deaths until November, albeit with a slightly later and higher ($n=780$) peak and faster decline. Thereafter deaths deviated from the usual seasonal pattern; fluctuating around 650 per week until late February rather than falling to 610 per week as expected. March 2022 saw a sharp rise in deaths by about 100 per week over their expected number.

The excess deaths are cumulated and shown in Panel B of Figure 1. For the first eight months, cumulative totals fluctuated around 0 in a fairly narrow band (rarely exceeding ± 100). However, from December cumulative excess deaths rose from -100 to over +300 by the end of February, and then rose more sharply, to +800 by the end of March. This figure also shows the rollout of original protocol and booster doses. The sustained rise in excess mortality from December coincides with the booster rollout.

The rise in excess mortality in the last four months of the April-to-March year was experienced by all ages except the 0-29 years group, who are mostly ineligible for boosters (Table 1). From the pre-booster era to the booster era excess mortality p-scores rose by seven percentage points for the 30-59 and 60-79 age groups and by ten percentage points for the oldest age group. In other words, the age groups most likely to use boosters show large rises in excess mortality after boosters are rolled out.

Table 1: Excess Mortality by Age Group: New Zealand 2021-22

Age Group	Mean Excess Mortality p-score		Change from pre-booster era to booster era*
	Pre-booster era	Booster era	
0 – 29	6.0	3.8	-2.2 [0.782]
30 – 59	-4.3	2.7	7.0 [0.017]
60 – 79	0.1	7.3	7.2 [0.003]
80 and above	0.3	10.4	10.1 [0.000]
ALL AGES	-0.2	8.2	8.4 [0.000]

Notes: The p-score is the percentage by which weekly deaths deviate from expected deaths. The pre-booster era is April to November 2021, and the booster era is December 2021 through March 2022.

* p-values for the null hypothesis of zero change in [].

III. Booster Impacts

The visual evidence of 400 cumulative excess deaths while boosters went from zero to over two million is suggestive, especially as the age-disaggregated data show no rise in excess deaths for the one group (0-29 years) mostly ineligible for boosters. Notably there is no similar temporal association with rollout of the original protocol doses. Also, only the last part of the rise in deaths in Figure 1 may be attributed to Omicron; community cases were first seen at the end of January and there is typically a 3-week infection-to-death lag (Gibson, 2022c).

Statistical analyses with cumulative data may face spurious regression problems, as Hendry (1980) famously showed with cumulative rainfall and the UK price level. Therefore, the remaining analyses use first-differenced data. Removing common trends gives smaller correlations; the $r=0.88$ for cumulative excess deaths and booster rollout shown in the figure becomes $r=0.37$ for their first differences (95% CI: 0.81 to 0.93, and 0.11 to 0.59).

Results of six different regressions, for first-differences of the time-series in Panel B of Figure 1, are reported in Table 2. Three are unconditional (bivariate) relationships while the others include control variables for original protocol doses (one can only be ‘boosted’ if already ‘fully vaccinated’) and for COVID-19 attributed deaths. The first set of regressions use OLS (with Newey-West robust standard errors), the next use distributed lag models, to allow for effects that accumulate over time (the 28-day lag corresponds to the common interval for attributing deaths after a positive PCR test to COVID-19), and the third set of regressions use instrumental variables to enable causal interpretations.

There are 16 excess deaths per 100,000 booster doses (95% CI: 6 to 25) with the unconditional OLS regression (Table 2). This rate rises to 32 using the 28-day lag, and is even higher, at 54, with instrumental variables. Thus, the OLS results can be viewed as conservative. With covariates included the coefficients have a tighter spread, with 12, 17, and 16 excess deaths per 100,000 booster doses, *ceteris paribus*, according to the OLS, distributed lag, and instrumental variables estimates.

Table 2: Estimates of the Relationship Between Booster Rollout and Excess Mortality

Method	No control variables	With control variables
Ordinary Least Squares (OLS)	15.6 (6.0 – 25.2)	12.1 (5.7 – 18.6)
Distributed Lag (DL)	32.1 (20.8 – 43.5)	17.0 (10.0 – 24.0)
Instrumental Variables (IV)	53.8 (9.8 – 97.9)	15.6 (4.6 – 26.5)

Notes: Coefficients show estimated excess deaths per 100,000 booster doses. 95% CI in (). Full results of the regressions are reported in Appendix C. $N=51$ for OLS and IV and $N=48$ for DL.

The regression results show statistical associations between booster rollout and excess deaths using observational data not randomized data. Thus, confounding from omitted relevant variables or reverse causation cannot be ruled out. Instrumental variables estimation allows quasi-experimental causal interpretations, subject to using valid instruments. In New Zealand the government frequently emphasized that pace of the vaccine rollout depended on Pfizer for the timing and quantity of shipments (Hipkins, 2021). This exogenous variation in doses available also altered timing intervals between doses (shorter when more doses were on hand). Satisfaction of the instrument relevance condition for vaccine availability shows in the high first-stage F -statistic (17.6). The exclusion restriction is that no pathway from available booster doses to excess mortality exists, except through doses actually given. Crowding-out could be an alternative pathway if vaccines had been purchased through usual channels; more Pfizer doses available might mean less spent on other life-saving drugs. Yet the vaccine taskforce was led by the Ministry of Business, Innovation and Employment (MBIE) rather than by the usual medicines buying agency (Pharmac), and purchases of Pfizer doses did not reduce Pharmac’s other spending so crowding-out seems unlikely.

An underlying theory of why X causes Y helps to interpret empirical relationships as causal. Here, dose-dependent adverse events may explain why booster rollout is associated with rising excess deaths while rollout of original protocol doses is not. Secondary analysis of serious adverse events reported in the mRNA vaccine RCTs shows higher risks with Moderna than with Pfizer (Fraiman et al, 2022), perhaps from dosage differences (100mg for Moderna

versus 30mg for Pfizer).⁶ The use of the Pfizer booster raises the accumulated dosage, which may then make these vaccine adverse events more likely.

The instrumental variables estimate of 16 (95% CI: 5 to 27) excess deaths per 100,000 booster doses, *ceteris paribus*, implies over 400 excess deaths in total given the booster doses administered in New Zealand to date. This estimate should not display omitted variables bias nor reflect reverse causation, which can also be further ruled out by noting that all-cause deaths needed for calculating excess mortality are reported with a time lag. Hence, few people could be aware, in near-real-time, of increased mortality risk that might spur them to get a booster.

IV. Conclusions

Weekly data on all deaths in New Zealand, from 2011 through the end of March 2022, are used here to calculate excess mortality during the rollout of COVID-19 vaccines. There is a close relationship between booster rollout and rising excess mortality. This relationship was not seen with the rollout of the original protocol vaccine doses. The age groups most likely to use boosters had 7–10 percentage point rises in excess mortality rates as boosters were rolled out while the age group that is mostly too young for boosters saw no rise in excess mortality. Instrumental variables estimates that exploit a plausible source of exogenous variation in the rate of administering booster doses suggest 16 excess deaths per 100,000 booster doses given, amounting to over 400 excess deaths from New Zealand’s booster rollout. Value of statistical life of these excess deaths is over \$1.6 billion. Even a small fraction of this (say, one percent) would have been sufficient to fund robust evidence on the impacts of rolling out COVID-19 booster vaccines.

⁶ Increased risk (relative to placebo group baselines) of serious adverse events were 151 per 100,000 vaccinated with Moderna and 101 per 100,000 vaccinated with Pfizer. These increased risks exceeded the risk reduction for COVID-19 hospitalization for vaccinees.

References

- Bardosh, K., de Figueiredo, A., Gur-Arie, R., Jamrozik, E., Doidge, J., Lemmens, T., ... & Baral, S. (2022). The unintended consequences of COVID-19 vaccine policy: why mandates, passports and restrictions may cause more harm than good. *BMJ Global Health*, 7(5), e008684.
- Coughlan, T. (2019). Is a life worth \$4.7 million? *Newsroom* February 21, 2019. <https://www.stuff.co.nz/national/politics/110753822/is-a-life-worth-47-million>
- Doshi P. (2020). Will covid-19 vaccines save lives? Current trials aren't designed to tell us. *BMJ*. 371; m4037.
- Doshi P, Godlee F, & Abbasi K. (2022). Covid-19 vaccines and treatments: we must have raw data, now. 376. *BMJ*, 376: o102.
- Food and Drug Administration [FDA] (2021) Transcript of 170th Vaccines and Related Biological Products Advisory Committee (VRBPAC) Meeting, Center for Biologics Evaluation and Research (CBER), Silver Spring, MD, October 21, 2021. <https://www.fda.gov/media/154950/download>
- Fraiman, J., Erviti, J., Jones, M., Greenland, S., Whelan, P., Kaplan, R., & Doshi, P. (2022). Serious adverse events of special interest following mRNA vaccination in randomized trials. *Mimeo* Available at SSRN: <https://ssrn.com/abstract=4125239>
- Gibson, J. (2022a). Widespread public misunderstanding of pivotal trials for COVID-19 vaccines may damage public confidence in all vaccines. *Frontiers in Public Health*, 10, 847658.
- Gibson, J. (2022b). Public misunderstanding of pivotal COVID-19 vaccine trials may contribute to New Zealand's adoption of a costly and economically inefficient vaccine mandate. *New Zealand Economic Papers*, 1-10. doi.org/10.1080/00779954.2022.2077812
- Gibson, J. (2022c). Hard, not early: putting the New Zealand Covid-19 response in context. *New Zealand Economic Papers*, 56(1), 1-8.
- Godlee, F. (2020). COVID-19: Less haste, more safety. *BMJ*, 370, m3258.
- Hendry, D. (1980). Econometrics-Alchemy or Science? *Economica*, 47, 387-406.
- Hipkins, C. (2021). Jabs rollout best we can do. *New Zealand Herald* July 2, 2021. <https://www.pressreader.com/new-zealand/new-zealand-herald/20210702/281483574363989>
- Kung, S., Doppen, M., Black, M., Hills, T., & Kearns, N. (2021). Correspondence: "Reduced mortality in New Zealand during the COVID-19 pandemic." *The Lancet*, 397(10268), 25.
- Krause, P., Fleming, T., Peto, R., Longini, I., Figueroa, J., Sterne, J., ... & Henao-Restrepo, A. (2021). Considerations in boosting COVID-19 vaccine immune responses. *The Lancet*, 398(10308), 1377-1380.
- Makary, M. (2022). Why America doesn't trust the CDC. *Newsweek* June 10, 2022. <https://www.newsweek.com/why-america-doesnt-trust-cdc-opinion-1713145>
- Lally M. (2021). The costs and benefits of Covid-19 lockdowns in New Zealand. *medRxiv*. <https://doi.org/10.1101/2021.07.15.21260606>
- Mathieu, E., Ritchie, H., Ortiz-Ospina, E., Roser, M., Hasell, J., Appel, C., ... & Rodés-Guirao, L. (2021). A global database of COVID-19 vaccinations. *Nature Human Behaviour*, 5, 947–953.
- Neil, M., Fenton, N., Smalley, J, Craig, C., Guetzkow, J., McLahlan, S., ... & Rose, J. (2022). "Official mortality data for England suggest systematic mis-categorisation of vaccine status and uncertain effectiveness of Covid-19 vaccination" *Working Paper* Queen Mary University of London, doi:[10.13140/RG.2.2.28055.09124](https://doi.org/10.13140/RG.2.2.28055.09124)
- Németh, L., Jdanov, D., & Shkolnikov, V. (2021). An open-sourced, web-based application to analyse weekly excess mortality based on the Short-term Mortality Fluctuations data series. *PloS One*, 16(2), e0246663. <https://doi.org/10.1371/journal.pone.0246663>

- Perrone, M., & Neergaard, L. (2021). FDA advisory panel rejects widespread Pfizer vaccine booster shots. *PBS News Hour* September 17, 2001. <https://www.pbs.org/newshour/health/fda-advisory-panel-rejects-widespread-pfizer-vaccine-booster-shots>
- Reynolds, C., Pade, C., Gibbons, J., Otter, A., Lin, K., Muñoz Sandoval, D., ... & Moon, J.. (2022). Immune boosting by B.1.1.529 (Omicron) depends on previous SARS-CoV-2 exposure. *Science*, eabq1841. <https://doi.org/10.1126/science.abq1841>
- World Health Organization [WHO] (2022). Interim statement on COVID-19 vaccines in the context of the circulation of the Omicron SARS-CoV-2 variant from the WHO Technical Advisory Group on COVID-19 Vaccine Composition (TAG-CO-VAC). January 11, 2022. <https://www.who.int/news/item/11-01-2022-interim-statement-on-covid-19-vaccines-in-the-context-of-the-circulation-of-the-omicron-sars-cov-2-variant-from-the-who-technical-advisory-group-on-covid-19-vaccine-composition>
- Yamamoto, K. (2022). Adverse effects of COVID-19 vaccines and measures to prevent them. *Virology Journal*, 19(1), 1-3. <https://doi.org/10.1186/s12985-022-01831-0>

Appendix A

Evidence from a Monthly Panel of OECD Countries

Data on the number of people vaccinated under original protocols for the COVID-19 vaccines and the number of booster doses given (both per 100 population) were obtained from *Our World in Data* (Mathieu et al, 2021) for the 31 countries (including New Zealand) that are members of the OECD and are part of the short-term mortality fluctuations database (Németh et al, 2021). These data were aggregated to monthly averages by country, for the August 2021 to May 2022 period, where the beginning of this period aligns with the start of booster rollouts to the general population in many of these countries and the end of the period is set by the availability of excess mortality estimates for a majority of these countries. In this sample, excess mortality p-scores (the percentage by which total deaths differ from expected deaths) average 11.8, the vaccination rate (for original protocol doses) averages 72.3% and booster use averages 28.3 doses per 100 people. In other words, deaths are running 12 percent higher than expected and the interest here is in seeing how the variation around this average relates to the use of the COVID-19 vaccines (both boosters and original protocol doses). While the estimated relationship is a conditional correlation, concern about omitted variables bias can be mitigated by using two-way fixed effects to control for time-invariant unobserved country factors and space-invariant temporal factors that might otherwise confound the relationship. The results of this regression are as follows:

HDFE Linear regression Absorbing 2 HDFE groups Statistics robust to heteroskedasticity	Number of obs = 285 F(2, 30) = 15.80 Prob > F = 0.0000 R-squared = 0.4747 Adj R-squared = 0.3835 Within R-sq. = 0.0815 Root MSE = 11.3363					
Number of clusters (iso_code) = 31						
(Std. Err. adjusted for 31 clusters in iso_code)						
excess_mortality	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
total_boosters_per_hundred	.4421837	.1499165	2.95	0.006	.1360135	.7483539
people_vaccinated_per_hundred	.3201347	.1136492	2.82	0.008	.0880321	.5522373
_cons	-23.84767	7.242109	-3.29	0.003	-38.63803	-9.057314

Absorbed degrees of freedom:

Absorbed FE	Categories	- Redundant	= Num. Coefs
iso_code	31	31	0 *
month	10	0	10

* = FE nested within cluster; treated as redundant for DoF computation

Excess mortality p-scores are 4.4 percentage points higher for every 10 doses per 100 people higher is the average booster rate ($p < 0.01$), controlling for the proportion of people who had been fully vaccinated under original protocols (noting that being fully vaccinated is a necessary condition for being boosted). In other words, excess mortality is higher where and when booster use is higher.

Appendix B: Regression Equations Used For Estimating Expected Weekly Deaths

	All-ages	Age 80 plus	Ages 60-79	Ages 30-59	Ages 0-29
Population (log)	989.163 (212.039)	432.633 (150.972)	360.709 (106.027)	91.129 (58.153)	104.645 (31.110)
Time index	-6.342 (3.712)	-1.931 (2.643)	-1.923 (1.856)	-0.670 (1.018)	-1.817 (0.545)
<i>Weekly fixed effects</i>					
Week_2	-10.200 (13.665)	0.300 (9.730)	-3.300 (6.833)	-4.200 (3.748)	-3.000 (2.004)
Week_3	6.700 (13.665)	14.400 (9.730)	-3.500 (6.833)	-1.200 (3.748)	-3.000 (2.004)
Week_4	-18.000 (13.665)	3.500 (9.730)	-15.800 (6.833)	-2.600 (3.748)	-3.100 (2.004)
Week_5	-19.600 (13.665)	1.300 (9.730)	-15.700 (6.833)	-1.600 (3.748)	-3.600 (2.004)
Week_6	-8.500 (13.665)	-0.800 (9.730)	-5.500 (6.833)	1.100 (3.748)	-3.300 (2.004)
Week_7	-20.700 (13.665)	-10.300 (9.730)	-3.100 (6.833)	-4.100 (3.748)	-3.200 (2.004)
Week_8	-20.200 (13.665)	-4.900 (9.730)	-10.300 (6.833)	-2.200 (3.748)	-2.800 (2.004)
Week_9	-12.072 (14.047)	2.630 (10.002)	-7.025 (7.024)	-4.090 (3.853)	-3.587 (2.060)
Week_10	-17.800 (13.665)	-0.200 (9.730)	-4.600 (6.833)	-7.600 (3.748)	-5.400 (2.004)
Week_11	-11.478 (14.041)	11.402 (9.997)	-13.899 (7.021)	-4.658 (3.851)	-4.323 (2.059)
Week_12	-6.900 (13.665)	8.400 (9.730)	-8.600 (6.833)	-2.400 (3.748)	-4.300 (2.004)
Week_13	-6.517 (13.665)	2.718 (9.730)	-1.552 (6.833)	-3.438 (3.748)	-4.263 (2.004)
Week_14	3.072 (14.056)	6.827 (10.008)	-2.505 (7.028)	1.390 (3.855)	-2.639 (2.061)
Week_15	-5.706 (14.056)	10.160 (10.008)	-6.061 (7.028)	-4.054 (3.855)	-5.750 (2.061)
Week_16	12.628 (14.056)	18.938 (10.008)	2.606 (7.028)	-2.721 (3.855)	-6.195 (2.061)
Week_17	14.294 (14.056)	19.494 (10.008)	-1.505 (7.028)	-2.165 (3.855)	-1.528 (2.061)
Week_18	12.517 (14.056)	23.160 (10.008)	-0.950 (7.028)	-3.832 (3.855)	-5.861 (2.061)
Week_19	32.739 (14.056)	31.160 (10.008)	9.495 (7.028)	-2.832 (3.855)	-5.084 (2.061)
Week_20	33.628 (14.056)	37.938 (10.008)	3.939 (7.028)	-4.610 (3.855)	-3.639 (2.061)
Week_21	33.850 (14.056)	33.827 (10.008)	5.272 (7.028)	-0.054 (3.855)	-5.195 (2.061)
Week_22	56.517 (14.056)	50.494 (10.008)	10.939 (7.028)	-1.721 (3.855)	-3.195 (2.061)
Week_23	54.405 (14.056)	52.716 (10.008)	8.161 (7.028)	-2.054 (3.855)	-4.417 (2.061)
Week_24	51.850 (14.056)	44.938 (10.008)	14.606 (7.028)	-1.943 (3.855)	-5.750 (2.061)
Week_25	74.739 (14.056)	61.938 (10.008)	13.383 (7.028)	1.835 (3.855)	-2.417 (2.061)
Week_26	79.566 (14.059)	69.988 (10.010)	10.462 (7.030)	-0.091 (3.856)	-0.792 (2.062)

Week_27	80.054 (14.105)	71.583 (10.043)	11.828 (7.053)	-0.585 (3.868)	-2.771 (2.068)
Week_28	100.721 (14.105)	82.805 (10.043)	21.495 (7.053)	-1.696 (3.868)	-1.883 (2.068)
Week_29	103.054 (14.105)	87.805 (10.043)	22.383 (7.053)	-4.363 (3.868)	-2.771 (2.068)
Week_30	122.054 (14.105)	103.028 (10.043)	23.717 (7.053)	-2.252 (3.868)	-2.438 (2.068)
Week_31	119.609 (14.105)	97.250 (10.043)	23.828 (7.053)	3.304 (3.868)	-4.771 (2.068)
Week_32	132.165 (14.105)	100.805 (10.043)	31.050 (7.053)	1.748 (3.868)	-1.438 (2.068)
Week_33	119.498 (14.105)	91.250 (10.043)	24.717 (7.053)	6.081 (3.868)	-2.549 (2.068)
Week_34	104.165 (14.105)	88.694 (10.043)	16.828 (7.053)	3.415 (3.868)	-4.771 (2.068)
Week_35	86.721 (14.105)	71.361 (10.043)	16.050 (7.053)	1.081 (3.868)	-1.771 (2.068)
Week_36	82.054 (14.105)	70.361 (10.043)	18.606 (7.053)	-2.919 (3.868)	-3.994 (2.068)
Week_37	99.054 (14.105)	77.472 (10.043)	29.050 (7.053)	-3.585 (3.868)	-3.883 (2.068)
Week_38	87.832 (14.105)	62.028 (10.043)	18.939 (7.053)	9.859 (3.868)	-2.994 (2.068)
Week_39	65.165 (14.105)	57.028 (10.043)	14.939 (7.053)	-2.919 (3.868)	-3.883 (2.068)
Week_40	49.828 (14.216)	54.006 (10.122)	1.994 (7.108)	-2.964 (3.899)	-3.207 (2.085)
Week_41	61.163 (14.223)	52.131 (10.127)	15.469 (7.112)	-4.096 (3.901)	-2.341 (2.086)
Week_42	26.496 (14.223)	31.909 (10.127)	4.691 (7.112)	-4.429 (3.901)	-5.675 (2.086)
Week_43	20.496 (14.223)	33.242 (10.127)	-2.198 (7.112)	-5.318 (3.901)	-5.230 (2.086)
Week_44	23.940 (14.223)	30.909 (10.127)	-3.420 (7.112)	0.460 (3.901)	-4.008 (2.086)
Week_45	27.496 (14.223)	30.576 (10.127)	1.025 (7.112)	-1.651 (3.901)	-2.452 (2.086)
Week_46	6.496 (14.223)	21.465 (10.127)	-5.531 (7.112)	-6.096 (3.901)	-3.341 (2.086)
Week_47	3.051 (14.223)	15.687 (10.127)	-4.309 (7.112)	-3.985 (3.901)	-4.341 (2.086)
Week_48	7.274 (14.223)	11.465 (10.127)	3.358 (7.112)	-2.763 (3.901)	-4.786 (2.086)
Week_49	-10.060 (14.223)	10.020 (10.127)	-15.531 (7.112)	0.126 (3.901)	-4.675 (2.086)
Week_50	-14.504 (14.223)	2.687 (10.127)	-4.420 (7.112)	-9.096 (3.901)	-3.675 (2.086)
Week_51	-1.726 (14.223)	7.020 (10.127)	-2.642 (7.112)	-5.207 (3.901)	-0.897 (2.086)
Week_52	-7.564 (13.549)	4.008 (9.647)	-6.556 (6.775)	-2.247 (3.716)	-2.769 (1.987)
<i>Shocks</i>					
Chch earthquake	149.722 (32.541)	-7.302 (23.169)	20.250 (16.272)	80.904 (8.925)	55.872 (4.772)
Mosque shooting	76.782 (32.275)	-5.019 (22.980)	47.986 (16.138)	18.584 (8.851)	15.231 (4.733)

Constant	-1,834.061	-2,473.826	-1,461.046	23.522	2,076.075
	(4,282.831)	(3,049.381)	(2,141.572)	(1,174.587)	(628.258)
R-squared	0.781	0.754	0.580	0.316	0.353

Notes: Estimated using $n=483$ weekly observations from the beginning of 2011 until the end of March 2020. Standard errors in (.). Coefficients from these equations are used to estimate expected deaths from April 2020 onwards.

Appendix C: Full Results of Regressions Relating Excess Mortality to Booster Rollout

	Ordinary Least Squares		Distributed Lag Model		Instrumental Variables	
	Bivariate	w/ controls	Bivariate	w/ controls	Bivariate	w/ controls
Booster doses	15.593** (4.758)	12.124** (3.217)	47.964 (35.886)	23.667 (14.438)	53.813* (21.927)	15.515** (5.446)
Original doses		-5.920 (3.570)		2.078 (16.168)		-4.897* (2.424)
COVID-19 deaths		14.058** (1.289)		13.024** (2.184)		14.272** (2.213)
Constant	7.246 (9.291)	10.969 (5.866)	0.241 (6.579)	8.864 (8.746)	-12.057 (7.322)	7.482 (5.656)
<i>Lagged variables</i>						
Booster _{t-1}			-37.487 (51.547)	-48.145 (26.630)		
Booster _{t-2}			-100.350 (67.151)	23.427 (22.153)		
Booster _{t-3}			122.014* (49.569)	18.062 (10.694)		
Original _{t-1}				3.676 (23.409)		
Original _{t-2}				-3.720 (22.311)		
Original _{t-3}				-8.082 (13.375)		
COVID-deaths _{t-1}				0.772 (2.561)		
COVID-deaths _{t-2}				-10.666** (3.565)		
COVID-deaths _{t-3}				26.391* (10.629)		
<i>Long-run Impact</i>						
Booster doses			32.141** (5.642)	17.011** (3.419)		
Original doses				-6.048 (3.841)		
COVID-19 deaths				29.520** (9.582)		
R-squared	0.140	0.744	0.634	0.863	0.391	0.739
Observations	51	51	48	48	51	51
First-stage F-test					15.8**	17.6**

Notes: Excess mortality, booster doses, and original doses are first differences of the series shown in Panel B of Figure 1. Doses are in units of 100,000, deaths in units of ones. The long-run impact for the distributed lag model is the sum of the contemporaneous and lagged terms. The instrumental variable is the available stock of vaccine doses. Heteroscedasticity and autocorrelation consistent Newey-West standard errors in (); **, * denote statistical significance at 1% and 5% level.