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NEW ZEALAND
WORK RESEARCH INSTITUTE

Published

New Zealand Work Research Institute, Auckland, New Zealand

ISBN (PDF): 978-1-99-101133-6

2024

Suggested citation: Meehan, L., Mitchell, L., & Pacheco, G. (2024). *Workforce vaccine mandates: The effect on vaccine uptake and healthcare workers' labour market outcomes*. New Zealand Work Research Institute, Auckland.

Workforce vaccine mandates: The effect on vaccine uptake and healthcare workers' labour market outcomes

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Abstract

As part of its COVID-19 policy response, the New Zealand government implemented vaccination mandates as a condition of ongoing employment for certain workers. This paper examines the effect of these mandates on vaccination uptake among mandated healthcare, education and corrections workers and on healthcare workers' labour market outcomes. This is enabled by New Zealand's linked population-wide administrative data, which includes a comprehensive national COVID-19 vaccination register linked to tax records to identify employment outcomes.

Overall, the results suggest that in the context of already-high vaccination rates, workforce vaccine mandates provided limited benefit in terms of increasing vaccination rates among mandated workers. Moreover, they negatively impacted healthcare workers' labour market outcomes, which may have had wider consequences in terms of exacerbating existing health workforce skills shortages.

JEL: C23; I12; I18
Keywords: COVID-19; vaccine mandates; vaccine uptake; healthcare workers; employment; earnings

Disclaimer

These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/.

The results are based in part on tax data supplied by Inland Revenue to Stats NZ under the Tax Administration Act 1994 for statistical purposes. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes, and is not related to the data's ability to support Inland Revenue's core operational requirements.

Funding

This research is funded by the Ministry of Health's COVID-19 research fund (grant number PROP-020). This grant included the quantitative analysis undertaken in this paper as well as qualitiative analysis undertaken in a companion paper: Dewar et al. (2024). *Hidden behind a cloak of silence and exclusion: A qualitative study of health professionals and mandated COVID-19 vaccinations.*

Acknowledgements

Thank you to the Ministry of Health for funding this research. Thank you to participants of the Economics of the Healthcare Workforce Workshop, NZ Association of Economists Conference and Social Wellbeing Agency Seminar for useful comments. Thanks to Peer Skov for reviewing an earlier version of this paper. Any errors or omissions remain the sole responsibility of the authors.

Contents

1 Introduction

As part of its COVID-19 policy response, the New Zealand (NZ) government implemented workforce vaccine mandates. These required certain types of workers, including health and disability, education, border and managed isolation, fire and emergency, police, defence and corrections staff, to be vaccinated in order to continue their employment. This paper examines the impact of these workforce vaccine mandates on the uptake of COVID-19 vaccinations among education, corrections and healthcare workers (HCWs)(RQ1: Research Question 1), and on the labour market outcomes of HCWs (RQ2: Research Question 2).

This paper adds to the very limited international evidence on the effect of workforce mandates on vaccination rates and labour market outcomes. Currently, there are only a handful of studies examining the effect of COVID-19 vaccine mandates on vaccine uptake, and most of these either study vaccine pass mandates (where proof of vaccination was needed to access non-essential services) as opposed to workforce mandates, or are limited to examining US nursing home staff mandates, which is only a subset of the wider health workforce. Moreover, there are few existing studies that use individual-level data, with almost all using state-/province-level data or nursing-home-level data. In addition, almost all of the existing studies using individual-level data involves self-reported survey information on vaccination status, rather than detailed administrative records. Indeed, there appears to be only one other study using individual-level data to look at COVID-19 vaccine workforce mandates (namely Rubenstein et al., 2023, which examines the effect of New York City municipal employee mandates on vaccine uptake). There is even less evidence on the effect of COVID-19 vaccine mandates on HCW labour market outcomes, with only a couple of studies examining US nursing home staffing.

The NZ experience, therefore, offers a natural experiment of the effects of stringently applied and enforced nationwide workforce vaccine mandates on vaccine uptake and labour market outcomes. This analysis is enabled by the existence of a comprehensive, population-wide vaccination database that has details of the type of vaccine received, the number of the dose administered, and the exact date the dose was received. This database is linked to various other administrative data sources, including employment details from tax records, which allow HCWs' employment outcomes to be tracked. As such, the NZ experience offers a unique opportunity to examine the effect of vaccine mandates and provide an evidence base to inform their use in future pandemic planning.

Given the value of COVID-19 vaccines in preventing severe illness and death (Tenforde et al., 2022), NZ was one of a number of countries that either implemented, or attempted to implement, vaccine mandates. The international experience highlights how controversial these policies are, and the difficulties inherent in making trade-offs between public health considerations and the impingement on individual rights and the risk of eroding trust in government and scientific institutions. Indeed, mandates can entrench distrust and provoke reactance (a motivation to counter a threat to one's freedom) (Bardosh et al., 2022; Sprengholz, Betsch, & Böhm, 2021; Sprengholz et al., 2022). This can potentially strengthen anti-vaccine sentiment generally and reduce acceptance not just of COVID-19 vaccinations (Schmelz & Bowles, 2022), but also of other vaccines (Dubé et al., 2021). In addition, there were concerns that HCW mandates would further exacerbate staff shortages. This is reflected in the degree of opposition to these policies, which resulted in mandates being abandoned in some countries (e.g. the UK), and/or facing legal challenges in others (e.g. the US and NZ). These complex ethical considerations and the resulting level of controversy surrounding these policies further heightens the importance of having a sound evidence base on the their effectiveness.

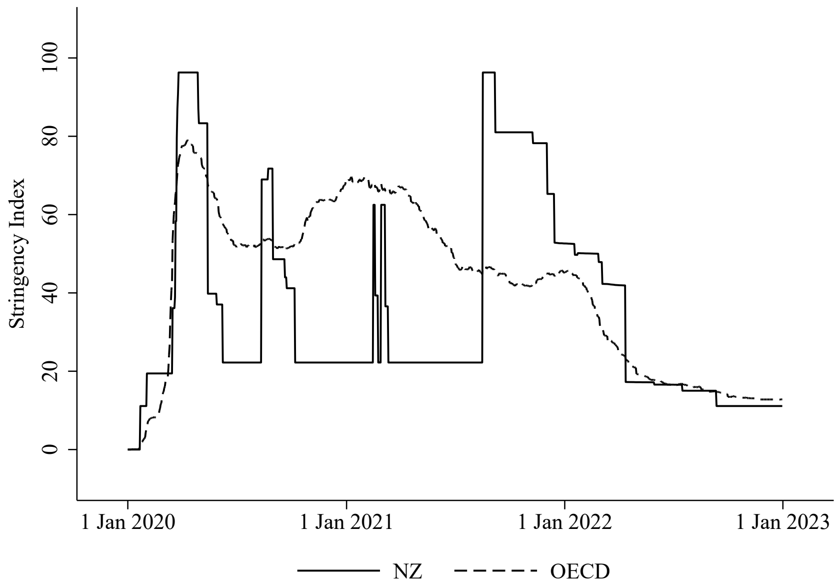
A difference-in-differences (DiD) approach comparing vaccine uptake and labour market outcomes among workers subject to the mandates and those who were not subject to the mandates allows the effect of workforce vaccine mandates to be separated from other initiatives aimed at boosting vaccination uptake. For example, NZ also implemented population-wide initiatives such as vaccine passes, whereby proof of vaccination was needed to access non-essential businesses. This differentiation is important from a policy perspective since vaccine passes are a "softer" mandate which potentially restrict access to non-essential businesses while workforce mandates are a "harder" mandate which potentially prevent someone from earning a living in their chosen profession. This is also particularly relevant in the context of professions with skill shortages, such as healthcare, where workforce mandates can further contribute to these shortages and hinder timely delivery of health services.

2 Background and policy context

The first case of COVID-19 was reported in NZ on 28 February 2020. In response, the government implemented a zero-COVID elimination strategy. While the specific measures in place to achieve this changed over time, the main measures used included strict lockdowns, closing the border to foreign nationals and imposing a period of managed isolated for those entering the country.

Figure 1 shows the stringency of NZ's policy response compared with the average for OECD countries. The spikes in the NZ series correspond to lockdowns, which involved the closure of non-essential businesses and services (including schools), strict restrictions on regional travel and the requirement to remain home except for essential travel (e.g. supermarket shopping, medical appointments etc.) or essential work (e.g. HCWs, supermarket workers etc.). These lockdowns occurred whenever cases of COVID-19 in the community were detected and were either nationwide or limited to specific regions where cases were detected. Although the specifics of what was permitted during lockdowns depended on the extent of community transmission, during the strictest lockdowns (officially known as Alert Level 4), NZ had the most stringent COVID-19 policy response in the world (Gibson, 2022b, 2022c). Figure 1 also shows that NZ's Stringency Index remained high even when restrictions began to ease in other countries. This is because NZ pursued an elimination strategy for an extended period of time, with corresponding policy responses including lockdowns.

Figure 1: COVID-19 policy response Stringency Index: NZ versus OECD

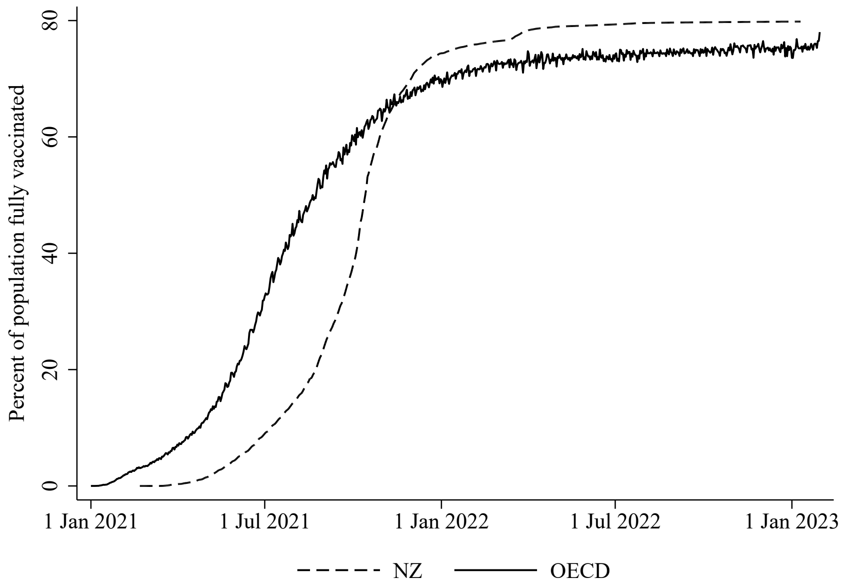


Note: OECD is a simple average of OECD countries with available data.

Source: Hale et al. (2021). Data accessed from https://github.com/OxCGRT/covid-policy-tracker on 27 January 2023

The first batch of COVID-19 vaccines arrived in NZ in February 2021. With the availability of vaccines, several additional vaccination-related policy measures were introduced. First, the government implemented a nationwide vaccine roll-out centered on the Pfizer vaccine. Due to supply issues, vaccines were initially offered to groups based on priority. Vaccinations were first available to vaccinators, and managed isolation workers and those they lived with, followed soon after by frontline HCWs. From March 2021, vaccine availability was extended to those most at risk of getting COVID-19 or developing serious illness as a result, including those aged 65 and over and those with underlying health conditions. Vaccines were then rolled-out to the general population in age groups. Those over 45 years were invited to get vaccinations from August 2021, those over 35 from September 2021 and everyone else was eligible from October 2021. However, when COVID-19 cases started to rise in the second-half of 2021, the roll-out proceeded slightly quicker than planned and vaccines were available to the entire population aged 12 and over from September 2021. Nonetheless, NZ's vaccine roll-out was initially slower than other countries, which is reflected in Figure 2 showing the percentage of people who were fully vaccinated over time compared with the OECD average. NZ's resultant vaccination rate was, however, relatively high likely reflecting a reasonably high willingness to comply with government recommendations, in addition to initiatives to encourage vaccination such as vaccine passes to access non-essential services, advertising campaigns, vaccination rate targets to come out of lockdowns etc.[1]

Figure 2: Share of population fully vaccinated: NZ versus OECD



Notes: OECD is a simple average of OECD countries with available data.
Source: Our World in Data COVID-19 database. Accessed from https://github.com/owid/covid-19-data/tree/master/public/data on 1 February 2023

In April 2021, the government announced vaccinations would be mandatory for workers in managed isolation and quarantine (MIQ) facilities from 1 May 2021. In July 2021, mandatory vaccinations were extended to port and airport workers. These vaccine mandates involved a relatively small number of workers. In October 2021, mandates were extended to a large number of workers, including teachers, HCWs,

[1]Due to data availability, Figure 2 shows the share of the total population who were fully vaccinated rather than the share of the total eligible population, or total adult population. But, if anything, the use of total population rather than total eligible population as the denominator biases down NZ's vaccination rates since NZ's population is relatively young compared with the average OECD country.

corrections prison workers, frontline fire and emergency service workers, police and defence force personnel. This extension of the number of workers covered by the mandates appears to be unexpected, with the government having earlier publicly ruled out the possibility of vaccine mandates, and with no media coverage of the possibility prior to the announcement in October. Deadlines were set for first and second vaccine doses, with staff who did not comply losing their jobs. Exemptions were only granted on medical grounds, and these had strict conditions and were administered centrally by the Ministry of Health. These were much narrower grounds for exemptions than, for example, the US, where COVID-19 vaccinations were mandated for HCWs employed by Medicare and/or Medicaid-accepting facilities, but exemptions were allowed on either medical or religious grounds (Rao et al., 2022).

Starting in October 2021, the government's COVID-19 response started to shift focus to a management rather than an elimination strategy, with vaccinations being a centrepiece of this strategy. Coming off the back of a nationwide lockdown in August to September 2021, and an ongoing lockdown in the largest city of Auckland, the government announced plans in October to implement a vaccine pass from early December 2021. This was a population-wide initiative, with anyone aged 12 or over requiring a vaccine pass to access public venues and non-essential businesses. Given this context, an important question is to what extent the workforce mandates increased vaccine uptake over-and-above other "softer" initiatives, particularly the population-wide vaccine passes.

In December 2021, the government formally shifted away from an elimination strategy and a new protection framework for managing COVID-19 was introduced. Over time, many measures such as border closures, managed isolation, and vaccine passes were rolled back. Workforce mandates started to be removed from April 2022, with the last mandates, including for HCWs, ending in September 2022. Workers who had lost their jobs due to non-compliance with the mandates were not entitled to reinstatement once these mandates were removed.

3 Literature

The first research question of this paper - whether mandates increase vaccination rates - relates to a substantial literature on the economics of infectious diseases and vaccinations. Some studies in this area look at the relationship between the prevalence of an infectious disease and vaccination rates, and suggest that people are responsive to disease prevalence. For the US, Philipson (1996) finds that the prevalence of measles reduces the age at which the first measles vaccination occurs, and Oster (2018) and Schaller, Schulkind, and Maghakian Shapiro (2017) find pertussis (whooping cough) outbreaks increase vaccination uptake. For Austria, Schober (2020) finds that measles outbreaks increase measles vaccine uptake. This literature also finds people respond to information. In particular, studies have found that MMR (measles, mumps, and rubella) vaccination uptake among children with highly educated mothers decreased in response to the controversial (and later retracted) study linking the MMR vaccine to autism (e.g. Anderberg, Chevalier, & Wadsworth, 2011).

This study is most related to quasi-experimental analyses in economics that examine vaccine mandates. Most existing evidence on the effectiveness of vaccine mandates relates to childhood immunisation as a condition for childcare or school entry. It mostly focuses on the US, which has a long history of using school-based mandatory vaccination laws to increase vaccination rates. For example, Carpenter and Lawler (2019) exploits the variation in the timing of mandate adoption across US states and applies a difference-in-differences methodology to the 2008-2013 waves of the National Immunization Survey-Teen. It finds strong evidence that Tdap vaccine mandates for middle school entry increase the uptake of the Tdap vaccine, and also have spill-over effects in raising vaccination rates of other, non-mandated vaccinations, such as the influenza vaccine. Abrevaya and Mulligan (2011) use data from the 1996-2006 National Immunization Survey (NIS) to examine daycare- and school-entry varicella (chickenpox) vaccine mandates in the US and find they increase immunisation rates. Lawler (2017) examines mandatory childcare-entry vaccinations versus non-binding recommendations to vaccine for hepatitis A and finds that recommendations increase vaccination rates among young children by 20 percentage points, while mandates increase rates by a further 8 percentage points. Moreover, recommendations only increase the probability that individuals will start the course of vaccinations, while mandates are effective at inducing them to complete the course. While the medical and public health literature examining mandates and childhood immunisations generally use data with less coverage, these also tend to find that school-entry mandates increase uptake (for a review, see Lee & Robinson, 2016).

There is limited existing evidence on the effectiveness of mandates in lifting vaccination rates in adults and outside of the US, and even less specifically focused on COVID-19 (Mello et al., 2022). Lindley et al. (2019) examines healthcare facility influenza vaccination mandates in the US, whereby employers implemented vaccines as a condition of employment, and assessed whether their effect differs depending on whether there are also state laws encouraging or mandating vaccinations. It finds that facility-level mandates increase influenza vaccination rates, with the increase being larger in states that have no or weaker laws. Carrera, Lawler, and White (2021) compares US states that did and did not implement laws encouraging or mandating influenza vaccinations for hospital workers and finds that these laws reduce pneumonia and influenza mortality rates among the general population. Although it did not examine the first-order effect of whether it increased vaccination rates among hospital workers, the presence of the second-order effect of reducing mortality suggests a first-order effect also occurred.

In terms of examinations of COVID-19 vaccine mandates, there are only a handful of studies, and all but one of these either study vaccine pass mandates (where proof-of-vaccination was needed to access non-essential services) as opposed to workforce mandates, or are limited to examining US nursing home staff mandates, with no existing evidence for other countries and/or the wider healthcare workforce. In terms of the vaccine pass mandate literature, Karaivanov et al. (2022) exploits the variation in timing of these measures across Canadian provinces to apply a difference-in-differences approach. It finds that the announcement of a mandate led to a surge in new vaccinations (a more than 60 % increase in weekly first doses). It also undertakes time-series analysis for each province and for France, Italy and Germany which corroborates this finding. Another paper using a synthetic control model by comparing six countries that introduced vaccine passes with 19 control countries, finds that vaccine passes led to an increase in vaccinations (Mills & Rüttenauer, 2022).

There are also several studies which examine the effect of COVID-19 vaccine passes by creating a synthetic comparison group of countries without vaccine passes. Mills and Rüttenauer (2022) compares six countries that introduced vaccine passes with 19 control countries and finds that vaccine passes led to an increase in vaccinations (Mills & Rüttenauer, 2022). Similarly, Oliu-Barton et al. (2022) finds that the introduction of vaccine passes in France, Germany and Italy led to an increase in vaccine uptake and a decrease in hospitalisations and deaths. Comparing Lithuania, which required a vaccine pass to access certain businesses and events, with Poland, which introduced a vaccine pass but did not impose any such restrictions (it was used as a tool for international travel only), Walkowiak, Walkowiak, and Walkowiak (2021) finds that Lituania had markedly higher vaccination rates than Poland.

The only study to use a synthetic-comparison-group methodology to examine the use of workforce vaccine mandates that we are aware of is Cohn et al. (2022), which compares New York City (NYC) to other similar US counties to examine the effect of a policy package that included workforce vaccine mandates for municipal employees along with vaccination passes and vaccine incentive payments. It finds that these measures increased vaccination rates in NYC relative to other US counties. However, the effect of the vaccine mandates cannot be separated from the other policies to encourage vaccination.

In terms of the literature on US nursing home staff vaccine mandates, Syme, Gouskova, and Berry (2022) examines COVID-19 vaccine mandates with a test-out exemption for Mississippi nursing home staff. It finds that compared with surrounding states without mandates, the vaccination rates among Mississippi nursing home staff increased more, but that the gains were minimal. However, this study only covered nursing home staff (not HCWs more generally), and examined a less stringent policy that allowed workers to return negative COVID-19 tests twice a week instead of vaccinating. McGarry et al. (2022) also examines nursing home staff and finds that COVID-19 vaccine rates increased the most in states with a mandate and no test-out option, followed by states with a mandate and a test-out option, and least in states with no mandate. Plummer and Wempe (2023) finds that following the US Supreme Court's upholding of the federal COVID-19 vaccine mandate for HCWs in Medicare- and Medicaid-eligible nursing homes, vaccination rates among nursing home staff increased more in states that did not have state-level vaccine mandates than in states that did have mandates.

As far as we are aware, Rubenstein et al. (2023) is the only study that examines workforce COVID-19 vaccine mandates more broadly than just nursing home staff. It examines vaccine mandates for NYC municipal workers. An announcement was made in July 2021 that all NYC municipal employees would either need to be vaccinated against COVID-19 or return a negative test each week from September 13 2021. On 20 October 2021, it was announced that the test-opt option would be removed from 1 November 2021, and all unvaccinated employees would be placed on unpaid leave from that date and eventually subject to termination. Comparing mandated municipal workers with all other working-age NYC residents, the study finds that the mandates did not increase vaccine uptake when the test-out option was available. However, uptake increased once the test-out option was removed. The comparison of NYC municipal workers and all other NYC working-age residents may, however, present issues since the characteristics of the two groups are not similar, with the comparison group having a much higher share of young people, men, Asians and Hispanics. Indeed, it is found that parallel trends does not hold as the vaccine uptake among the comparison group increased at a faster pace than the municipal employees group in the pre-treatment period. Moreover, a potentially larger issue with the apparent faster uptake of vaccinations after the test-out option was removed is that the population of municipal employees changed over time. Thus, as the paper acknowledges, the apparent faster increase in vaccinations among municipal employees could have been due to unvaccinated employees leaving their jobs and, therefore, no longer being counted in the treatment group, and because any new municipal employees would have been required to be vaccinated. Given unvaccinated workers were placed on unpaid leave and faced termination and any new employees needed to prove their vaccination status, it is difficult to know whether the stricter mandate without the test-out option led to an increase in vaccination uptake or merely changed the composition of the treatment group.

While staffing shortages are an important potential unintended consequence of COVID-19 vaccine mandates, there is even less evidence on worker labour market outcomes than on the effect of mandates on vaccine uptake. McGarry et al. (2022) finds no evidence of increased nursing home staffing shortages in states with COVID-19 vaccine mandates. However, this finding is based on self-reported facility-level nursing home staff shortages, which is subject to possible misrepresentation (Plummer & Wempe, 2023). Plummer and Wempe (2023), which examines the federal COVID-19 vaccine mandate, appears to be the most related to our study. It using nursing home payroll data to measure staffing levels (e.g. staff hours per resident per day) rather than self-reported staff shortage data due to concerns about possible misrepresentation. It finds that the mandates did not have a material impact on staffing levels. Once again, these studies are limited to nursing home staff rather than the wider healthcare workforce.

In terms of NZ evidence, we are not aware of any studies using quasi-experimental methods to examine the impact of vaccine mandates. However, there is a small economics literature examining the costs versus benefits of vaccine mandates. Lally (2021) undertakes cost-benefit analyses and finds that the costs of vaccine mandates for the general population are likely to far outweigh the benefits. However, because HCWs are more likely to come into frequent and close contact with sick people, the benefits of vaccine mandates *may* outweigh the costs for these workers (emphasis in original). Education workers are less likely to come into contact with people at high risk from COVID-19, and therefore, Lally (2021) finds that the costs of mandates outweigh the benefits for these workers.

Given the limited existing evidence on the impact of COVID-19 vaccine mandates on HCW vaccine uptake and workforce labour market outcomes, this paper makes a significant contribution to the literature. The existing quasi-experimental literature on mandates measures vaccination status using survey data for the most part, with some exceptions such as Karaivanov et al. (2022), which uses Canadian provincial data (rather than individual-level data), and the aforementioned studies on US nursing homes (McGarry et al., 2022; Plummer & Wempe, 2023), which use weekly data on staff vaccination rates at the nursing-home-facility level. The lack of studies using individual-level data stems from the fact that most existing analysis is for the US, where there is a lack of immunisation registries (Abrevaya & Mulligan, 2011). It seems that the only study to use individual-level data is Rubenstein et al. (2023), which examines NYC municipal employee mandates. However, it appears that the authors used aggregated information on individual vaccine records rather than having access to individual-level records as they state that they could not look at changes to municipal employee staffing due to only having access to aggregated data. In contrast, NZ's Ministry of Health has a comprehensive, population-wide vaccination database which includes information on all COVID-19 vaccine doses administered in NZ, as well as records of COVID-19 vaccines received overseas.[2] Anonymised individual-level vaccine records are available to researchers and linked to a rich set of data on individuals' characteristics via Stats NZ's Integrated Data Infrastructure (IDI), including employment records via tax data.

Moreover, improving the evidence base in this area is particularly important from a policy perspective given the problem of skill shortages in healthcare, and the possibility that mandates can further contribute to these shortages and hinder the timely delivery of essential health services. This is also particularly relevant given the degree of controversy surrounding mandates. This is reflected in the qualitative literature, which suggests there is limited support for COVID-19 vaccine mandates among HCWs. For example, Woolf et al. (2022) finds that only 18% of surveyed UK HCWs favoured mandatory COVID-19 vaccination. Even more strikingly, a German survey found that few respondents were opposed to being vaccinated against COVID-19 if vaccinations were encouraged but voluntary (3.3%), but a much higher share were opposed to being vaccinated if vaccinations were mandatory (16.5%) (Schmelz & Bowles, 2022). This highlights the potential issue of reactance (Bardosh et al., 2022; Sprengholz, Betsch, & Böhm, 2021; Sprengholz et al., 2022), which can strengthen anti-vaccine sentiment generally (Schmelz & Bowles, 2022). In addition, there have been legal challenges to mandates. While the US Supreme Court upheld the federal vaccine mandate, these legal challenges were partially successful in NZ. The NZ courts ruled that the mandates were an unjustifiable limitation on the right to refuse medical treatment in the case of defence and police staff (although the ruling was made after the mandates for these workers had been lifted), but that this limitation was justified in the case of HCWs and teachers. In the UK, vaccine mandates for NHS staff were set to come into force, but were abandoned amidst implementation issues (such as difficulties confirming the vaccination status of staff) and concerns about the loss of key staff (McKee & Schalkwyk, 2022).

[2] During the period which the mandates were in place, NZ also required those entering the country to prove their COVID-19 vaccination status. Thus the COVID-19 vaccination register includes reliable information on vaccinations administrated overseas.

4 Data

We use population-wide linked administrative data from Stats NZ's Integrated Data Infrastructure (IDI). Our main data sources are the Inland Revenue Department's (IRD) Employer Monthly Schedule (EMS) data, which allows us to identify which individuals worked in sectors subject to COVID-19 vaccination mandates, and the Ministry of Health's COVID-19 vaccination register, which allows us to identify vaccination uptake and mandate compliance.

We first define our population of interest for evaluating the impact of vaccine mandates on vaccination uptake (RQ1), including how we identify those subject to the vaccine mandates and those who complied with the mandates. We then define the population of interest for evaluating the impact of vaccine mandates the labour market outcomes of HCWs (RQ2). Lastly, we define a range of demographic and socioeconomic descriptive variables used for both RQ1 (vaccine uptake) and RQ2 (HCW labour market outcomes) analyses.

4.1 RQ1 vaccine uptake

4.1.1 Creating a sample of employed individuals

To study the impact of COVID-19 vaccination mandates on vaccination uptake, we begin by identifying a cohort of individuals who were employed before the COVID-19 vaccines were largely available to the public (the first vaccine was administered in NZ on 19 February 2021, and vaccinations were initially limited to vaccinators and then MIQ staff and their families) and before any announcements of potential COVID-19 vaccine mandates were made. Identifying a specific cohort avoids the issue of vaccination rates among mandated workers changing due to changes in the workforce composition over time (particularly given that unvaccinated workers were required to leave vaccine-mandated roles), which, as mentioned in the context of Rubenstein et al. (2023)'s analysis, would lead to an overestimate of the effect of mandates on vaccine uptake. Specifically, we use the personal details and IRD EMS data in the IDI to identify all working-aged people (aged 16-60) with positive earnings (in terms of receiving positive wages and salaries) in March 2021. March 2021 is chosen as the reference point not only because it is prior to widespread vaccine access and vaccination mandate announcements, but also because it is the end of the financial year in NZ. This gives 2,083,155 individual-job observations.

Next, to account for multiple job holdings, we observe each individual in their main job. A person's main job is defined as the job with the main ("M"-type) tax code in the EMS data. If there are multiple jobs with M codes, their main job is defined as the one with the highest earnings for in the reference month of March 2021. This gives 1,946,859 individual observations.

The EMS data provide the Australia and New Zealand Standard Industry Classification 2006 (ANZSIC06) code relating to each employer-employee relationship, allowing us to identify the industry each individual is employed in. Since we require this industry information to identify individuals who were subject to COVID-19 vaccination mandates, we exclude those for whom their main job is missing an ANZSIC06 industry code. This leaves us with 1,941,942 individual observations with main job industry information.

We exclude those who died during our study period, leaving 1,940,370 individuals. Finally, we drop a very small number of individuals with dubious COVID-19 vaccination records (potentially driven by measurement error); for example, those with their first dose date after their second dose date, or those with missing first and second dose records but an 'additional dose' record. The resulting sample comprises 1,940,115 individuals.

4.1.2 Identifying individuals subject to COVID-19 vaccination mandates

Through examining iterations of the COVID-19 Public Health Response (Vaccinations) Order 2021 ('the Order'), and media releases on the the NZ Government's official website (beehive.co.nz) and Ministry of Health website, we are able to identify the announcement dates and commencement dates for each group of individuals who became subject to the COVID-19 vaccination mandates.

In Schedule 2 of the Order, "groups of affected persons" are defined in 10 'parts'. These parts describe categories of work. For example, Part 7 is "Groups in relation to health and disability sector". We match the work description in each 'part' to a 7-digit ANZSIC06 industry code. We then categorise each of the 500+ 7-digit ANZSIC06 industries into one of the following three categories:

1. Industries barely covered by COVID-19 vaccination mandates
2. Industries partially covered by COVID-19 vaccination mandates
3. Industries heavily covered by COVID-19 vaccination mandates

Consequently, we observe which of the above categories each employed individual fell into, according to the ANZSIC06 industry code relating to their main job in March 2021.

The classification into 'barely', 'partially' and 'heavily' industries warrants further explanation. As the administrative data does not include information on an individual's occupation, we focus on industry of employment. This means that, for example, an administrator employed by a hospital would be classified as a health sector worker. In some cases, industries align well with the categories of work defined in the 'parts' of the Order, including in the case of HCWs since the definition was much broader than health practitioners (discussed below). In some cases, it only partially aligns. For example, MIQ workers were mandated by the Order under *Part 1 - Groups in relation to managed quarantine facilities*. However, MIQ facilities were hotels in NZ, and employment is therefore identified by the *H440000 Accommodation* ANZSIC06 industry code, which also includes all other hotel workers not employed at MIQ facilities. Thus, mandated hotel workers cannot be differentiated from non-mandated workers using industry classification codes, and we categorise *H440000 Accommodation* as a partially mandated industry.

As mentioned, fortunately the HCW category aligns well with Part 7 *Groups in relation to health and disability sector* which covered not only frontline HCWs, but also care workers (such as those in aged-care facilities), and workers whose role involved being within two metres of health practitioners or members of the public.[3] Thus, it aligns well with the ANZSIC06 industry code classification of *Q84 Hospitals*, *Q85 Medical and Other Health Care Services* and *Q85 Residential Care Services*. Note, however, that the use of ANZSIC06 industry codes means we cannot include workers who fall under the Order definition but are not employed in the health industry. For example, cleaners who are employed by a cleaning company but work in a hospital would be captured by the Order Part 7 definition but fall under ANZSIC06 *N7311 Building and Other Industrial Cleaning Services*.

Moreover, we will compare HCWs with workers in barely-mandated industries. These are industries such as *A Agriculture, Forestry and Fishing*, *E Construction* and *M Professional, Scientific and Technical Services* and all their associated sub-industries, where it is clear that government mandates did not apply generally. We refer to these as 'barely' mandated industries rather than non-mandated industries because there may have still been a few workers in some of these industries who were subject to mandates. For example, an IT worker employed by an IT firm and therefore falling under ANZSIC06 *M7000 Computer System Design and Related Services* but contracted to work in a hospital could have fallen under the definition of the Order, but is defined as belonging to a barely mandated industry. However, these small classification issues do not undermine the validity of the approach as the important point for our analysis is that the share of workers subject to mandates in 'heavily'

[3] Specifically 1. Health practitioners; 2. Workers who carry out work where health services are provided to members of the public by one or more health practitioners and whose role involves being within 2 metres or less of a health practitioner or a member of the public for a period of 15 minutes or more; 3. Workers who are employed or engaged by certified providers and carry out work at the premises at which health care services are provided; 4. Care and support workers.

mandated industries is much higher than the share in 'barely' mandated industries.

Another potential issue is that some employees were subject to employer-imposed, rather than government-imposed, vaccine mandates, which may downward bias our estimates. For example, most central and local governments, universities and even a few private businesses required staff to be vaccinated. We have classified employees in industries where employer-imposed mandates were common, such as central and local government, as partially mandated rather than barely-mandated industries to avoid them appearing in the comparison group for our DiD analysis. However, there may still be some employees in the barely-mandated comparison group who were subject to mandates. This issue will result in an underestimate of the effect of the mandates.

4.1.3 Identifying compliance with COVID-19 vaccination mandates

Our main interest is in HCWs, but as comparison points and to characterise compliance with the COVID-19 vaccination mandates, we also examine corrections prison and education workers. These two additional groups have clear links with ANZSIC06 industry codes. As mentioned, other workers covered by COVID-19 vaccination mandates are harder to identify via industry classifications because the Order did not mandate the whole industry.

Table 1: Key dates for COVID-19 vaccination mandates for health, corrections, and education industries

(1) Order	(2) ANZSIC06 industry	(3) Announcement date	(4) First dose deadline	(5) Second dose deadline
Part 7: Health and disability sector	Q84	11-Oct-21	15-Nov-21	1-Jan-22
	Q85	11-Oct-21	15-Nov-21	1-Jan-22
	Q86	11-Oct-21	15-Nov-21	1-Jan-22
Part 8: Corrections prisons	O771400	23-Oct-21	6-Nov-21	8-Dec-21
Part 9: Affected education services	P801	11-Oct-21	15-Nov-21	1-Jan-22
	P802	11-Oct-21	15-Nov-21	1-Jan-22

Table 1 details the mandate announcement dates and deadlines. In late January 2022, the government added a mandatory booster dose to the Order for these groups, but the deadline was less clear cut and we therefore do not examine this.[4]

For individuals employed in industries under Parts 7, 8 and 9 of the Order, we use the Ministry of Health COVID-19 vaccination register to identify workers' compliance with the COVID-19 vaccination mandate. The vaccination register allows us observe if and when each individual received a first dose and second dose of an approved

[4]For HCWs, the booster dose deadline was the later of either 25 February 2022 or 183 days after the date of the second dose.

COVID-19 vaccine. By comparing actual vaccination dates with the mandated vaccination deadline dates, we categorise individuals into one of the following vaccination compliance categories:

1. Individuals who got vaccinated likely irrespective of vaccination mandates:
   - people who received their first dose of a COVID-19 vaccine before the vaccination mandate was announced, and who subsequently received a second dose before the mandated second dose deadline
2. Individuals who got vaccinated likely due to vaccination mandates:
   - people who received their first dose after the vaccination mandate was announced but before the mandated first dose deadline, and their second dose before the mandated second dose deadline
   - people who missed the mandated first dose deadline, but had both their first and second dose before the mandated second dose deadline
3. Individuals who were unvaccinated or uncompliant with vaccination mandates:
   - people who received no doses of a COVID-19 vaccine
   - people who received only one dose of a COVID-19 vaccine
   - people who received a first dose but had their second dose after the mandated second dose deadline

Anticipatory effects were considered but public information indicates it is unlikely to be an issue. Even if the mandates had been anticipated, vaccine-hesitant individuals were unlikely to get vaccinated until it was clear that this would be required as a condition of continued employment. However, there are several factors which suggest that they were not anticipated. The first vaccine mandates covering MIQ workers were announced in April 2021, and these were extended to port and airport workers in July 2021. However, we argue that these early vaccine mandates would not have induced an anticipatory effect among the vaccine hesitant for at least two reasons. First, in September 2020 the government had explicitly ruled out the possibility of COVID-19 vaccine mandates. The decision to mandate MIQ, port and airport workers could therefore be seen as a contradiction to earlier government media statements, and thus the prospect of vaccine mandates being applied more broadly was generally dismissed due to the government's initial sentiment against vaccine mandates. Second, the first set of vaccine mandates applied to a relatively small number of workers and occurred well before the HCW announcements, making it unlikely that the MIQ, port and airport mandates would have led HCWs to believe they would also be mandated.

This is supported by a Google news search for 'vaccine mandates health workers NZ' (and variants thereof), which reveals no media coverage on the possibility of HCW vaccine mandates before the government made the official announcement on 11 October 2021. In addition, a series of Ministry of Health-commissioned surveys about attitudes towards COVID-19 vaccines in NZ were carried out between December 2020 and October 2021. These included free-form responses and concerns about vaccine mandates were only reported in the last (October 2021) survey (HorizonResearch, 2021), which was the only one conducted after the mandate announcements. These pieces of evidence, in conjunction with the fact that the policy decisions at the time were being made quickly in a crisis-management mode suggests that HCW vaccine mandates were unlikely to have been widely anticipated.

4.2 RQ2 healthcare labour market outcomes

4.2.1 Creating a sample of employed individuals

To study the impact of COVID-19 vaccine mandates on health workforce labour market outcomes, we focus on two populations of workers: HCW and barely-mandated workers. As described in Section 5.2, we use the barely-mandated workforce as a comparison group to help isolate the mandate effect from the industry-specific and general pandemic effects on job separation rates.

We create the HCW and barely-mandated worker populations from the 2019 usually-resident population table in the IDI and observe all working aged (16-60 years) individuals with positive earnings (in terms of receiving positive wages and salaries) in March 2019 and who did not die throughout our study period. We use March 2019 as the last end-of-tax year before the COVID-19 pandemic began. To account for multiple job holdings (as with RQ1), we observe individuals in their main job in March 2019, defined first by the job with an M-type (main income source) tax code and then by the job that provides highest labour earnings. We then categorise individuals into industries using the 7-digit ANZSIC06 code associated with their main job in March 2019. As outlined in Section 4.1.2 for RQ1, we also link the 7-digit ANZSIC06 industry codes to the work description provided in the Order to identify whether a worker was heavily, partially, or barely subject to the COVID-19 vaccination mandates. This enables us to define a sample of 156,417 HCWs and 1,242,822 barely-mandated workers benchmarked in March 2019.

4.2.2 Identifying individuals' vaccination status

As described in Section 4.1.3, we identify a worker's vaccination status using the Ministry of Health's nationwide COVID-19 vaccination register in the IDI. For the HCW population, we define vaccination status as an indicator equal to 1 if the individual was double vaccinated and in compliance with the vaccination mandate and equal to 0 if the individual was unvaccinated or uncompliant with the mandate. We create this vaccination indicator consistent with the three vaccination compliance categories as defined for RQ1 in Section 4.1.3. Namely, we make the vaccination indicator equal to 1 if the HCW was vaccinated regardless of mandates or vaccinated likely due to the mandates and equal to 0 if the HCW was unvaccinated or uncompliant with the mandates.

For the barely-mandated worker population, we define vaccination status as an indicator equal to 1 if the individual was (at least) double-vaccinated and equal to 0 if the individual was unvaccinated or only received a single vaccination. While there were no mandate deadlines for the barely-mandated workers, we follow the same definitions as used for the HCW in Section 4.1.3 to make the two groups as comparable as possible. Therefore, we consider a worker to be double-vaccinated if they received at least two vaccinations as recorded in the vaccination register. Further, to be consistent with the HCW sample, we drop a very small number of barely-mandated workers who have dubious vaccination records.

4.2.3 Identifying individuals' overseas spells

It is important that we restrict our sample to workers who reside in NZ during our study period because vaccination records and earnings data could be misleading/missing for workers who spend considerable time overseas. Thus, we use the overseas spells border movement data to count the total number of days each worker spent outside NZ throughout the study period of March 2019 to November 2022. To identify workers who reside in NZ, we use Stats NZ's '12/16-month rule' [5] whereby they differentiate long-term migrants from short-term migrants (i.e., visitors) if the individual is in NZ for 12 out of 16 months in a given period. We adjust this 12/16 rule to our 45-month study period. This is equivalent to approximately 34/45 months, corresponding to about 1,020 days. Thus, we define a worker as residing in NZ if they were inside NZ for at least 1,020 days during our study period (approximately 1,350 days). Equivalently, a worker is defined as not residing in NZ if they were outside NZ for at least 330 days. This equates to 5.7% of HCWs and 1.1% of barely-mandated workers.

Overall, this leaves us with the following four groups for RQ2 analysis:

- Vaccinated HCW residing in NZ (144,087)

[5] As detailed on Stats NZ's 'Migration Data Transformation' project webpage, https://www.stats.govt.nz/about-us/what-wedo/current-projects/migration-data-transformation-project/ (accessed on 3 May 2022) and Stats NZ (2017).

- Vaccinated barely-mandated workers residing in NZ (1,068,726)
- Unvaccinated HCW residing in NZ (12,330)
- Unvaccinated barely-mandated workers residing in NZ (174,099)

4.2.4 Defining labour market outcomes

We use IRD tax data in the IDI to obtain each worker's labour market information and examine HCWs' employment and earnings outcomes. We create unique individual-month observations by observing individuals in their main job each month following the same criteria as set out in Section 4.1. This results in a balanced monthly panel spanning 45 months from March 2019 to November 2022 for all HCW and barely-mandated workers. This equates to almost 63 million worker-month observations.

For both HCWs and barely-mandated workers, we define an *employment indicator* that equals 1 if the individual received positive wages and salaries in a given month, and 0 otherwise. We also create a monthly *labour earnings* variable showing the wages and salaries earned from the individual's main job per month.

We then define two additional industry-specific employment indicators. The first is a *same industry indicator*. For HCW, this indicator equals 1 if the individual is employed in the health industry and equals 0 otherwise (i.e. if the person is employed in a different industry or not employed). For barely-mandated workers, this indicator equals 1 if the individual is employed in the same 1-digit ANZSIC06 industry that they were in March 2019 (the '1-digit reference industry'),[6] and equals 0 otherwise.

The second industry-specific employment indicator is a *same industry indicator conditional on employment*. For HCW, this indicator equals 1 if the individual is employed in the health industry and equals 0 if the individual is employed but not in the health industry. For barely-mandated workers, this indicator equals 1 if the individual is still employed in their 1-digit reference industry and equals 0 if the individual is employed in a different 1-digit ANZSIC06 industry. These two same-industry indicators provide us with a means to examine the extent to which the mandates impacted on the exit of unvaccinated HCWs from the health industry.

We also examine rates of industry switching descriptively to examine whether workers exiting the health industry were being replaced, or order to gauge whether job separations caused by the mandates may have contributed to the industry's worker shortages. However, this measure of job accessions is of secondary concern since if there were excess workers leaving the health industry due to the mandates, it is difficult to see how these gaps could have been filled by job accessions. Most healthcare

[6]The use of a 1-digit reference industry roughly matches the level of the health industry, which is the 1-digit industry *Q Health Care and Social Assistance* less social assistance services.

jobs are skilled roles that require high levels of training and experience, making it difficult to fill gaps from within the domestic labour market in the short-term. Historically, like other developed countries, NZ has filled these immediate gaps with inward migration. However, during the pandemic, offshore recruitment of both migrants and returning New Zealanders was very limited due to NZ's border restrictions,[7] and, at this time, NZ also had more restrictive migration conditions for HCWs than competing anglophone countries (such as Australia and Canada).[8]

For job separations, we examine whether HCWs move out of the industry, either into employment in another industry or out of employment entirely, by defining a *left health sector* indicator that equals 1 if a HCW is no longer employed in the health industry and 0 if they remain employed in this industry. For barely-mandated workers, this indicator equals 1 if the individual is no longer employed in their 1-digit reference industry, and 0 if they remain employed in their reference industry.

For job accessions, we examine whether barely-mandated workers move into the health sector by defining a *joined health sector* indicator that is equals 1 if a barely-mandated worker becomes employed in the health industry, and 0 otherwise. For HCWs, this indicator equals 1 if they become employed in a barely-mandated industry. As discussed, our main interest is in job separations, and our population of interest is less well suited to measuring accessions as this measure does not consider NZ residents who moved from not being in employment to being HCWs, those who move from overseas to employment as a HCW, and those who move from working in partially-mandated industries to being HCWs.

4.3 RQ1 and RQ2 additional descriptive variables

We link several administrative datasets in the IDI to obtain demographic and socioeconomic information for all individuals in our RQ1 and RQ2 samples.

We use the personal details table to obtain an individual's age, sex and ethnicity.[9] To define an individual's migrant status, we use the Department of Internal Affairs births register to identify if the individual was born in NZ or not.

[7] The Ministry of Health was allocated priority access to 300 MIQ rooms a month for critical HCWs from November 2021, approximately 20 months after the NZ border restrictions were implemented. In addition, between November 2021 and February 2022, only 147 of the 900 allocated places were used.

[8] For example, during the period being investigated, Australia and Canada offered migrant nurses, midwives and doctors residency visas immediately, while in NZ, until December 2022, nurses midwives and some doctors (depending on their specialty) were only eligible for temporary work visas and had to wait at least two years before becoming eligible to apply for residency.

[9] We use Stats NZ's prioritisation rules to create mutually exclusive ethnicity categories prioritised as follows: Māori; Pacific peoples; Asian; Middle Eastern, Latin American, or African (MELAA); Other; European.

We use Stats NZ's derived address notification dataset to identify the meshblock associated with each individual's last known residential address. We use the meshblock code to identify each individual's residential District Health Board (DHB) area, and to identify the level of socioeconomic deprivation in the area as measured by the NZ Deprivation Index (NZDep) 2018.[10]

5 Method

5.1 RQ1: Vaccine uptake

To estimate the extent to which the COVID-19 vaccination mandates increased vaccination uptake, we employ a difference-in-differences estimation strategy. By comparing the vaccination uptake of HCWs (treatment group) with the vaccination uptake of individuals employed in barely-mandated industries (comparison group), we can isolate the effects of the mandates from the general increase in vaccinations due to other population-wide initiatives, such as vaccine passports. Specifically, we estimate the following model set out by Equation 1:

$$Y_{it} = \alpha + \beta HCW_i + \gamma Post + \delta(HCW_i.Post) + \epsilon_{it} \tag{1}$$

where Y is an indicator of vaccination uptake, equal to 1 if the individual is double-vaccinated and 0 otherwise.[11] T represents treatment status, where $HCW = 1$ for HCWs and $HCW = 0$ for individuals who work in barely-mandated industries. We observe individuals in two time periods as indicated by $Post$, where $Post = 0$ indicates the time period before the vaccine mandate was announced (i.e. the pre-announcement time period) and $Post = 1$ indicates the time period after the vaccine mandate was announced (i.e. the post-announcement time period). ϵ_{it} denotes the error term. To account for the possibility of serial and intra-group correlation, robust standard errors clustered at the level of the individual are used (Bertrand, Duflo, & Mullainathan, 2004).

The coefficient of interest δ reveals the treatment effect of COVID-19 vaccination mandates on vaccination uptake. β is the treatment-group specific effect that accounts for permanent differences between the average vaccination uptake of the treatment group compared to the comparison groups (e.g. to account for the fact that mandated health workers may have permanently higher vaccination rates than workers in the

[10]The NZDep is a measure of socioeconomic deprivation based on the meshblock a person lives in, with a meshblock being roughly equivalent to a city block. The Index ranges 1-10, with 1 being the least deprived areas and 10 being the most deprived areas.

[11]As a robustness test, we also define vaccination uptake by only the first dose, and it did not qualitatively change the results.

comparison group). γ is the time trend common to the treatment and comparison groups.

5.2 RQ2: Healthcare worker labour market outcomes

As discussed, we examine the effect of mandates on several labour market outcomes for HCWs, including employment, earnings and job accession and separation rates. Note that while the data can reveal whether an unvaccinated health worker left employment, the data does not tell us why. It may be that some workers left voluntarily for non-mandate reasons, such as retirement, family pressures, or a career change, etc. It also may be due to the COVID-19 vaccination mandates. Therefore, to estimate the effect of the vaccine mandates on labour market outcomes for HCW, we use a triple difference-in-differences (DDD) analysis comparing unvaccinated and vaccinated HCWs with unvaccinated and vaccinated barely-mandated workers over time. Since labour market outcomes can be measured on a monthly basis, we use dynamic DiD estimates, although we also conduct robustness checks using two-period DiDs.

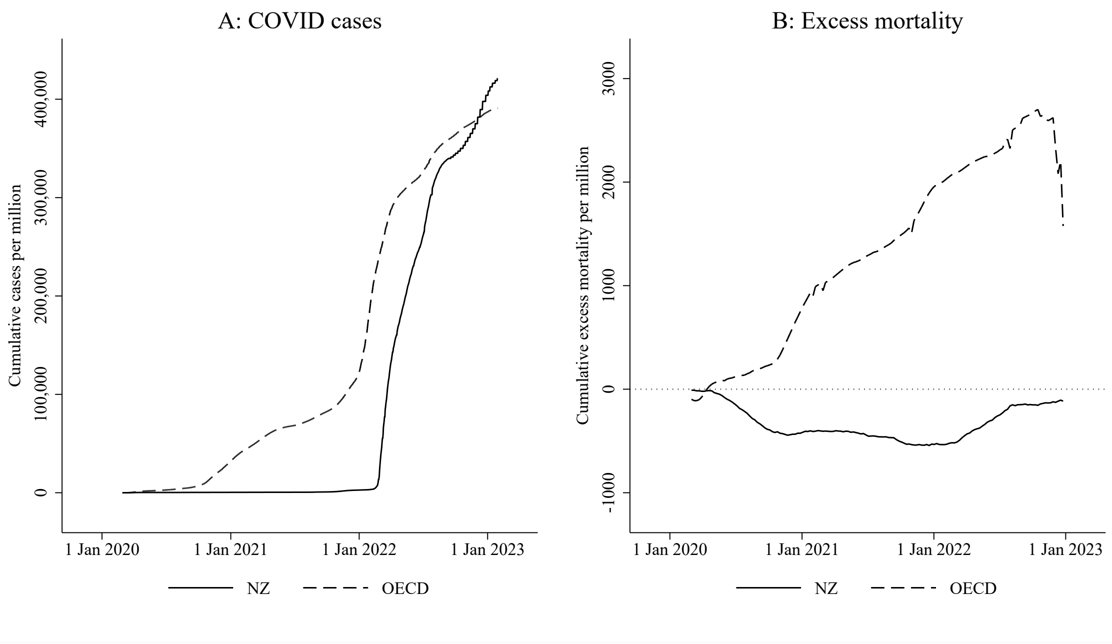
In terms of the treatment and comparison groups, we consider two potential options. One involves comparing the labour market outcomes of unvaccinated versus vaccinated HCWs, and another involves comparing the outcomes of unvaccinated HCWs versus unvaccinated barely-mandated workers. Both these options have potential advantages and issues, and we thus instead employ a triple difference method that incorporates both comparisons on the basis that the difference between two biased DiD estimates is potentially unbiased as long as the bias is the same in both estimators (Olden & Møen, 2022).

In terms of the comparison of unvaccinated HCWs with vaccinated HCWs, this has the advantage that both groups are in the same industry, and thus faced the same set of industry labour market conditions. However, there may be spillover effects since, for example, unvaccinated HCWs leaving the healthcare industry may increase skills shortages, improving the bargaining power and labour market outcomes of vaccinated HCWs. Alternatively, it could have potentially increased the pressure on vaccinated HCWs and expedited their exit from the health industry.

Furthermore, a comparison of unvaccinated HCWs with unvaccinated barely mandated workers may also be problematic if the conditions in the two industries diverged for reasons other than the vaccine mandates. This is a realistic concern given the pandemic itself may have impacted the health industry differently to other industries. For example, there may have been increased demand for HCWs, particularly relative to other industries, many of which intially saw a reduction in demand due to COVID-19 lockdowns (although, after this initial reduction, the labour market was buoyant and skills shortages became an issue in many industries). This high demand for HCWs could have potentially reduced (increased) job separation (accession) rates in the post-pandemic time period regardless of the imposition of mandates. On the other hand, the pandemic may have increased (decreased) job separation (accession) rates by creating a more stressful work environment for HCWs in a way that was not experienced by other industries, thus leading to higher HCW job separation rates regardless of the vaccine mandates.

However, this potential issue was likely to be less problematic in the case of NZ relative to other countries as NZ experienced few COVID-19 cases until March 2022 (Figure 3, Panel A) so did not have the same issues of COVID-19 cases straining the health system. Indeed, NZ's excess mortality - the cumulative difference between the reported number of deaths since 1 January 2020 and the projected number of deaths for the same period based on previous years, shown in Figure 3, Panel B - was actually negative while the OECD average was large and positive. This reflects that COVID-19 containment measures also greatly reduced the number of cases of, and deaths associated with, influenza and other respiratory illnesses, and the lockdown reduced accident-related deaths (e.g. by heavily reducing traffic volumes) (Kung et al., 2021).

Figure 3: Cumulative COVID cases and excess mortality: NZ versus OECD



Notes: OECD is a simple average of OECD countries with available data.
Source: Our World in Data COVID-19 database. Accessed from https://github.com/owid/covid-19-data/tree/master/public/data on 1 February 2023.

Nevertheless, HCW stress was still an issue in NZ, due to factors such as staff shortages which were exacerbated by border closures. In addition, staff illness and isolation requirements also contributed to staff shortages. From March 2020, anyone who had potentially came into contact with a COVID-19-positive case, including causal contact such as visiting a supermarket within the same window of time, had to isolate at home for 14 days, which led to a large number of people isolating despite the low COVID-19 case numbers. While the rules around who had to isolate and for how long eased over time, up until September 2022, it was still necessary for those with COVID-19 and their household contacts to isolate for 7 days. Between September 2022 and August 2023, only those with COVID-19 had to isolate. While these isolation rules created staffing shortages across many industries, not just healthcare, given there was a higher probability of a HCW coming into contact with someone with COVID-19, this issue may have impacted HCWs more. Thus, to account for the possibilities of spillover effects and differential industry effects, we estimate implement a DDD approach.

This DDD approach takes the form:

$$\begin{aligned} Y_{sit} =& \alpha + \beta_0 UV_i + \beta_1 HCW_i + \beta_2 (UV_i.HCW_i) + \gamma_0 Post + \gamma_1 (UV_i.Post) \\ &+ \gamma_2 (HCW_i.Post) + \gamma_3 (UV_i.HCW_i.Post) + \delta X_{sit} + \epsilon_{sit} \end{aligned} \tag{2}$$

where Y_{sit} refers to the outcome of interest for individual i in sector s at time t. In terms of the treatment groups, $UV_i = 1$ for those who are unvaccinated and $UV_i = 0$ for those who are vaccinated, while $HCW_i = 1$ for HCWs and $HCW = 0$ for barely-mandated workers. X_{sit} is a vector of control variables, such as age, gender, ethnicity and socioeconomic status and robust standard errors are clustered at the individual level.

This approach provides four different estimators of the effect of vaccine mandates on labour market outcomes. The sum of the estimators $\hat{\gamma}_0$, $\hat{\gamma}_1$, $\hat{\gamma}_2$, $\hat{\gamma}_3$ provides an "undifferenced" estimate of the effect on unvaccinated HCWs. To the extent that there may be other factors that may have affected the labour market outcomes of both unvaccinated barely-mandated and HCWs that were unrelated to the mandates, we can difference out a common "unvaccinated" effect by using $\hat{\gamma}_2 + \hat{\gamma}_3$. A third estimator $(\hat{\gamma}_1 + \hat{\gamma}_3)$ uses the difference between unvaccinated HCWs and vaccinated HCWs to remove any common "HCWs" effect that both the unvaccinated and vaccinated share. Finally, a "triple difference estimator", $\hat{\gamma}_3$, differences out both vaccination status and sector effects and is therefore our coefficient of interest. That is, $\hat{\gamma}_3$ is the effect of mandates on unvaccinated HCWs relative to vaccinated HCWs and unvaccinated barely-mandated workers.

Because we have labour market outcomes on a monthly basis, as our preferred estimation method, we employ a dynamic DDD of the form:

$$
\begin{aligned}
Y_{sit} =& \alpha + \beta_0 UV_i + \beta_1 HCW_i + +\beta_2 (UV_i.HCW_i) + \sum_{e \neq -3, e=-15}^{13} \gamma_0.M_e \\
&+ \sum_{e \neq -3, e=-15}^{13} \gamma_1 (UV_i.M_e) + \sum_{e \neq -3, e=-15}^{13} \gamma_2 (HCW_i.M_e) \\
&+ \sum_{e \neq -3, e=-15}^{13} \gamma_3 (UV_i.HCW_i.M_e) + \delta X_{sit} + \epsilon_{sit}
\end{aligned} \tag{3}
$$

where M_e are event time indicators, where $M_e = 0$ is the vaccine mandate announcement in October 2021. That is, we track the outcome on a monthly basis from July 2020 to November 2022.

In general, the treatment effect is expressed as a percentage of the counterfactual (P_e) to provide a comparable sense of the magnitude of the effect. Using the example of employment:

$$
P_e = \frac{\gamma_3}{E[\tilde{Y_{sit}}|t]}.100 \tag{4}
$$

where P_e is the ratio of the parameter of interest (γ_3) from Equation 3 at event time t to the predicted employment outcome conditional on event time t, multiplied by 100.

6 Results: RQ1 - Vaccine uptake

This section presents results for RQ1 on vaccination uptake. It first presents summary statistics by COVID-19 vaccination mandate categories as well as vaccination compliance categories. It then examines vaccination uptake over time for different groups of mandated workers as well as barely-mandated workers. Finally, it presents DiD results.

6.1 Summary statistics

By COVID-19 vaccination mandate categories

Table 2 presents descriptive statistics of the March 2021 worker cohort categorised by whether they were in barely-mandated, partially-mandated or heavily-mandated industries (as defined in Section 4.1.2). The largest group is the barely mandated category, which comprises nearly 1.3 million workers. The heavily mandated group has just over 460,000 workers and the partially mandated group has nearly 190,000 workers.

Table 2: Descriptive statistics of workers in industries that barely, partially, or heavily faced COVID-19 vaccination mandates

(1) Characteristic	(2) Barely mandated	(3) Partially mandated	(4) Heavily mandated
Number of workers	1,289,007	189,501	461,604
Had at least one vaccine (%)	92.18	94.96	95.00
Demographic			
Age (years)	37.52	39.58	37.96
Female (%)	39.00	58.63	71.31
Gender unknown (%)	0.06	0.05	0.06
European (%)	53.81	55.97	53.54
Māori (%)	15.21	15.11	14.76
Pacific (%)	7.64	7.41	5.69
Asian (%)	19.04	16.89	22.06
MELAA/Other (%)	3.90	4.39	3.63
Ethnicity unknown (%)	0.40	0.23	0.32
NZ born (%)	62.44	61.92	59.29
Socioeconomic			
NZ Deprivation Index 2018	5.51	5.30	5.43
Monthly income in March 2021 ($)	6,522	7,127	5,445
Monthly earnings in March 2021 ($)	6,438	7,050	5,349
Monthly earnings from main job in March 2021 ($)	6,330	6,941	5,224

Notes: This table presents demographic and socioeconomic characteristics of all individuals who were employed in March 2021, categorised by whether their industry barely faced COVID-19 vaccination mandates, partially faced COVID-19 vaccination mandates, or heavily faced COVID-19 vaccination mandates (as defined in Section 4.1.2). Percentages may not always add up to 100 due to rounding.

The average age of workers in each group is fairly similar, with the barely-mandated group and the heavily-mandated being around 37-38 years old, on average, while the partially-mandate group is nearly 40 years old, on average. About 95% of both the partially-mandated and heavily-mandated groups received at least one COVID-19 vaccination, while this is only 92% for the barely-mandated group.

Females make up a much larger percentage of the heavily mandated group (71.3%) compared to the partially-mandated group (58.6%) and the barely mandated group (39%). This is unsurprising since the heavily-mandated industries are mostly female-dominated health and education industries, while the barely-mandated industries include those such as construction, which are more male-dominated.

Just over half of all three groups are European, about 15% are Māori, and about 7% are Pacific peoples. This suggests that the composition of Māori and Pacific peoples' in each COVID-19 mandate industry group is approximately representative of the composition of Māori and Pacific peoples' in the general New Zealand population. Approximately 60% of each group were born in NZ. The average deprivation level is fairly similar across the three COVID-19 mandate groups, sitting at around 5.4.

Across all income and earnings measures, workers in partially-mandated industries earn more than those in barely-mandated or heavily-mandated industries. Those in mandated industries received an average total income of $7,127 in March 2021, while those in barely mandated and heavily mandated industries received $6,521 and $5,445, respectively. These figures are similar when looking at total monthly earnings received in March 2021. Further, across all groups, approximately 98% of total monthly earnings received in March 2021 were from the individual's main job, suggesting few workers received additional earnings from secondary jobs.

Table 3: District Health Board compositions of workers in industries that barely, partially, or heavily faced COVID-19 vaccination mandates

(1) Characteristic	(2) Barely mandated	(3) Partially mandated	(4) Heavily mandated
Number of workers	1,289,007	189,501	461,604
District Health Boards			
Northland	2.68	2.65	3.43
Waitemata	12.99	10.37	12.78
Auckland	11.10	10.70	10.33
Counties Manukau	12.72	8.98	10.12
Waikato	8.12	7.04	8.62
Lakes	2.08	2.29	2.34
Bay of Plenty	4.99	3.44	4.82
Tairawhiti	0.99	0.62	1.01
Taranaki	2.34	1.67	2.34
Hawke's Bay	3.57	2.63	3.44
Whanganui	1.10	0.90	1.49
Mid-Central	3.22	4.01	4.13
Hutt Valley	2.96	5.34	3.35
Capital and Coast	5.81	15.50	7.32
Wairarapa	0.84	0.73	0.93
Nelson/Marlborough	3.23	2.26	2.97
West Coast	0.58	0.61	0.52
Canterbury	12.21	10.50	11.94
South Canterbury	1.30	0.73	1.07
Southern	6.85	8.78	6.85
Area outside DHB	.s	.s	.s
DHB unknown	0.32	0.23	0.18

Notes: This table shows the percentage of workers that reside in each District Health Board as at their last recorded address on March 2021, categorised by whether the individual's main job industry barely faced Covid-19 vaccination mandates, partially faced COVID-19 vaccination mandates, or heavily faced Covid-19 vaccination mandates. Percentages may not always add up to 100 due to rounding. Notation ".s" means counts have been suppressed in accordance with Stats NZ confidentiality rules.

Table 3 shows the percentage of each COVID-19 mandate industry group that reside in each DHB region as at March 2021. The DHB composition of each group is fairly similar. A notable exception is that 15% of workers in the partially-mandated group reside in the Capital and Coast DHB, whereas this statistic is only about 6% and

7% for the barely-mandated and heavily-mandated groups, respectively. This is likely because the large majority of central-government employees reside in Wellington and public sector jobs were more likely to be subject to COVID-19 vaccination mandates.

By COVID-19 vaccination mandate compliance categories

For the mandated industries of interest (health, corrections, and education), we provide summary statistics by COVID-19 vaccination mandate compliance categories. This splits each group into three categories (as defined in Section 4.1.3): those who were likelyvaccinated regardless of mandates, those who were vaccinated potentially due to mandates, and those who did not comply with the mandates.

Part 7 - Healthcare workers

Table 4 presents the demographic and socioeconomic characteristics of HCWs who were subject to COVID-19 vaccination mandates under Part 7 of the Order. This group comprises 171,486 workers, of which 89.2% (152,937) were vaccinated before the mandate was announced and hence were likely vaccinated regardless of the mandate. About 5.5% (9,426) were vaccinated within the mandate announcement and vaccination deadlines and hence could have potentially vaccinated due to the mandate. The remaining 5.3% (9,123) were unvaccinated or uncompliant. Of those in the unvaccinated or uncompliant group, 21% received at least one COVID-19 vaccine.

This reasonable share of partially vaccinated uncompliant workers raises the possibility that some were at least somewhat open to being vaccinated. We do not know why they did not receive a second dose, but it may have been due to factors such as experiencing an adverse effect from the first dose.

HCWs who were vaccinated before the mandate was announced and those who did not comply with the mandate were 41 years old on average, while those who may have gotten vaccinated potentially due to the mandates were slightly younger, at 38 years old on average. The large majority of all three groups were female, ranging from 80-84 %. Those who were born in NZ make up a larger share of those who could have potentially been vaccinated due to the mandate than the other two compliance groups.

In terms of differences by ethnicity, European HCWs were about as likely to be in each of the three compliance groups. Asian HCWs were more likely to be in the group that would have been vaccinated regardless of the mandate. Māori and Pacific HCWs were more likely to be in the group that were potentially vaccinated due to the mandate compared with the other two compliance groups.

While our data cannot shed light on the reasons behind these ethnicity patterns, it could potentially raise issues of the coercive nature of the mandates further eroding trust in public institutions among these workers. This is a particular issue in relation

Table 4: Descriptive statistics of workers in health industries that heavily faced COVID-19 vaccination mandates

(1) Characteristic	(2) Vaccinated regardless of mandate	(3) Vaccinated potentially due to mandate	(4) Unvaccinated or uncompliant with mandate
Number of workers	152,937	9,426	9,123
Had at least one vaccine (%)	100.00	100.00	20.91
Demographic			
Age (years)	41.07	38.04	41.46
Female (%)	80.80	84.15	83.76
Gender unknown (%)	.s	.s	.s
European (%)	52.33	47.77	53.47
Māori (%)	11.07	26.96	18.28
Pacific (%)	5.87	9.17	7.04
Asian (%)	26.96	12.00	14.21
MELAA/Other (%)	3.58	4.07	3.98
Ethnicity unknown (%)	.s	.s	.s
NZ-born (%)	52.19	69.35	55.48
Socioeconomic			
NZ Deprivation Index 2018	5.42	6.44	5.85
Monthly income in March 2021 ($)	6822	4935	5368
Monthly earnings in March 2021 ($)	6736	4742	5195
Monthly earnings from main job in March 2021 ($)	6563	4626	5060

Notes: This table presents demographic and socioeconomic characteristics of all individuals who were employed in health industries in March 2021, categorised by vaccination mandate compliance behaviour. Percentages may not always add up to 100 due to rounding. Notation ".s" means counts have been suppressed in accordance with Stats NZ confidentiality rules.

to Māori HCWs given the historical legacies of colonisation affecting trust among the Māori population. This is reflected in, for example, NZ's General Social Survey, which shows that 44% of Māori rated their trust in parliament as low compared with 29% of the total population, and 47% of Māori feeling that the public had little to no influence on government decision making, versus 37% of the total population (Stats NZ, 2018). Moreover, qualitative research involving Māori, Pacific and disability communities undertaken as part of the government's equity review of the COVID-19 response highlights that these groups felt that mandates further disadvantaged them (Paipa et al., 2023). Qualitiative research on NZ HCWs specifically also highlights that Māori HCWs felt that the mandates were another measure that was being imposed upon them and contributed to their sense of a loss of control (Dewar et al., 2024).

There are also clear differences by socioeconomic status. Health workers who likely would have vaccinated regardless of mandates and workers who did not comply with mandates have an average deprivation level of approximately 5.5, while those who could have potentially gotten vaccinated due to mandates have a higher average index of nearly 6.5 (where a higher index indicates a higher level of deprivation). Similarly, health workers who could have been vaccinated potentially due to the mandates have lower monthly income and monthly earnings than those in the other two groups. This may reflect that health workers with lower socioeconomic status experienced stronger financial imperatives and therefore were more likely to comply with the mandate to avoid losing their jobs.

Part 8 - Corrections workers

Table 5 presents the demographic and socioeconomic characteristics of workers in corrections industries who were subject to a COVID-19 vaccination mandate under Part 8 of the Order. This group comprises 8,937 workers, of which 90.1% (8,055) were vaccinated before any mandate announcement and hence were likely vaccinated regardless of the mandate, 5.5% (492) were vaccinated after the mandate announcement but before the mandate deadlines and hence could have potentially been vaccinated due to the mandates, and the remaining 4.4% (390) did not comply with the mandate. These statistics are fairly similar to the vaccination compliance shown by health workers in Table 4. Of the corrections workers who did not comply with the mandate, 9% received at least one vaccine dose.

Corrections workers in the first and third compliance groups were 43 years old on average, while those who may have gotten vaccinated due to the mandates are slightly younger, at 40 years old on average. Again, Māori and Pacific Peoples are overrepresented among those who were vaccinated potentially due to the mandate compared to those who likely would have vaccinated regardless of the mandate and those who did not comply with the mandate.

Unlike the results for health workers, corrections workers have a more balanced gender split, where those who were vaccinated before or after the mandate announcement have approximately a 50:50 female-to-male ratio, while it was about 60:40 for those who did not comply with the mandate. This could reflect that women are more likely to be secondary income earners within families, and, therefore, could have been less concerned about losing their jobs by not complying. It could also reflect that women are more likely to be COVID-19 vaccine hesitant (Toshkov, 2023) and more likely to experience adverse effects from the vaccine (Duijster et al., 2023; Green et al., 2022).

A similar story is evident when looking at the socioeconomic status variables across vaccination mandate compliance categories as with HCWs. Corrections workers who may have gotten vaccinated due to the mandates have a higher deprivation score and lower monthly earnings and monthly income than workers in the other two compliance categories. However, unlike HCWs, corrections workers who were not compliant look more similar to group two (those who may have gotten vaccinated due to the mandates) than group one (those who would have likely gotten vaccinated regardless of the mandate) in terms of socioeconomic status indicators.

Table 5: Descriptive statistics of workers in corrections industries that heavily faced COVID-19 vaccination mandates

(1) Characteristic	(2) Vaccinated regardless of mandate	(3) Vaccinated potentially due to mandate	(4) Unvaccinated or uncompliant with mandate
Number of workers	8,055	492	390
Had at least one vaccine (%)	100.00	100.00	9.23
Demographic			
Age (years)	43.23	40.02	42.85
Female (%)	50.54	48.78	57.69
Gender unknown (%)	.s	.s	.s
European (%)	52.03	42.68	48.46
Māori (%)	19.03	25.61	20.77
Pacific (%)	12.33	20.73	14.62
Asian (%)	12.33	6.71	10.00
MELAA/Other (%)	4.21	4.27	3.85
Ethnicity unknown (%)	.s	.s	.s
NZ-born (%)	60.86	63.41	58.46
Socioeconomic			
NZ Deprivation Index 2018	5.60	6.43	6.16
Monthly income in March 2021 ($)	9349	8444	8305
Monthly earnings in March 2021 ($)	9327	8414	8279
Monthly earnings from main job in March 2021 ($)	9264	8371	8231

Notes: This table presents demographic and socioeconomic characteristics of all individuals who were employed in corrections industries in March 2021, categorised by vaccination mandate compliance behaviour. Percentages may not always add up to 100 due to rounding. Notation ".s" means counts have been suppressed in accordance with Stats NZ confidentiality rules.

Part 9 - Education workers

Table 6 presents the demographic and socioeconomic characteristics of workers in education industries who were subject to a COVID-19 vaccination mandate under Part 9 of the Order. This group comprises 122,397 workers, of which 83.4% (102,084) were vaccinated before any mandate announcement and hence were likely vaccinated regardless of the mandate, 10% (12,285) were vaccinated within the mandate announcement and vaccination deadlines and hence may have potentially been vaccinated due to the mandate, and the remaining 6.6% (8,028) did not comply with the mandate. Thus, education industries have a lower percentage of workers that were vaccinated regardless of mandates compared with health and corrections industries, and a higher percentage of workers who potentially got vaccinated due to the mandates. While this could reflect differences in the degree of vaccine hesitancy, it may, however, reflect that, unlike health and corrections workers, education workers did not have early access to the vaccine (discussed more below). As with health and corrections workers, a reasonable minority (24%) of education workers in the non-compliant group received at least one vaccine dose.

Table 6: Descriptive statistics of workers in affected education industries that heavily faced COVID-19 vaccination mandates

(1) Characteristic	(2) Vaccinated regardless of mandate	(3) Vaccinated potentially due to mandate	(4) Unvaccinated or uncompliant with mandate
Number of workers	102,084	12,285	8,028
Had at least one vaccine (%)	100.00	100.00	23.65
Demographic			
Age (years)	42.09	36.39	40.48
Female (%)	83.02	84.69	86.06
Gender unknown (%)	.s	.s	.s
European (%)	66.57	50.79	57.47
Māori (%)	14.41	34.68	25.15
Pacific (%)	5.04	7.28	6.24
Asian (%)	10.76	4.64	6.54
MELAA/Other (%)	3.19	2.59	3.21
Ethnicity unknown (%)	.s	.s	.s
NZ-born (%)	69.38	81.39	68.95
Socioeconomic			
NZ Deprivation Index 2018	5.07	6.37	5.90
Monthly income in March 2021 ($)	4989	4167	4005
Monthly earnings in March 2021 ($)	4918	3954	3798
Monthly earnings from main job in March 2021 ($)	4829	3867	3712

Notes: This table presents demographic and socioeconomic characteristics of all individuals who were employed in education industries in March 2021, categorised by vaccination mandate compliance behaviour. Percentages may not always add up to 100 due to rounding. Notation ".s" means counts have been suppressed in accordance with Stats NZ confidentiality rules.

There is a bit more variation across compliance categories in age among education workers than the health and corrections workers. Education workers who would have likely vaccinated regardless of mandates are 42 years old on average, with those who did not comply were slightly younger, at 40 years old on average. However, those who were potentially vaccinated due to the mandates were younger, at 36 years old on average. Like the health industries, the large majority of all three groups are female, ranging 83-86%.

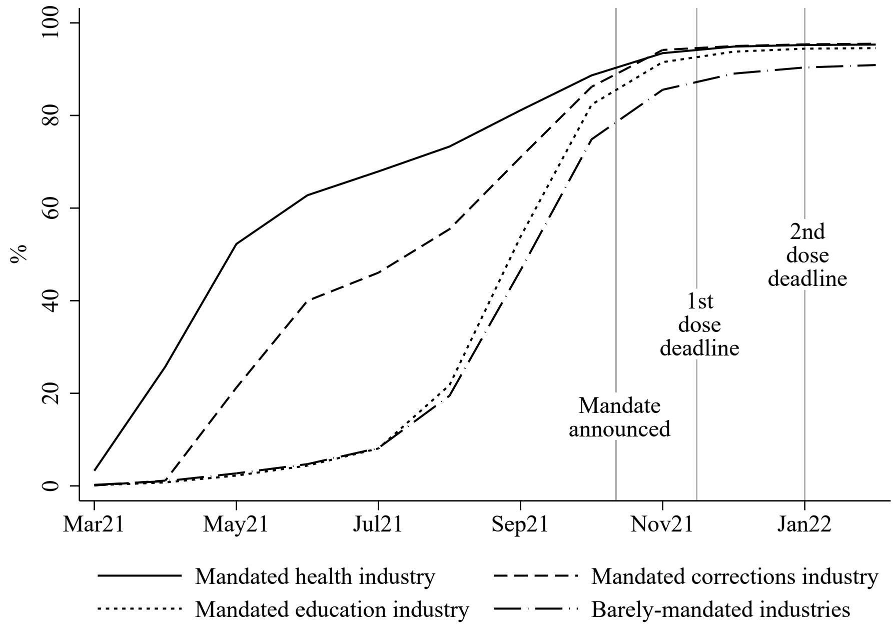
European and Asian education workers are more likely to have been vaccinated regardless of mandates, compared to the other two groups. Like the health and corrections workers, Māori and Pacific education workers are more likely to have potentially been vaccinated due to the mandates compared to groups one and three. Over 80% of education workers who were potentially vaccinated due to mandates were born in NZ, while this statistic is nearly 70% for the other two groups.

Like health and corrections workers, education workers who were vaccinated potentially due to the mandate have a higher deprivation score on average, compared with those that were vaccinated regardless of mandates or those who did not comply. However, unlike the health and corrections workers, education workers who were not compliant had the lowest monthly income and monthly earnings measures, compared to groups one and two.

6.2 Vaccination uptake over time

Figure 4 shows the cumulative share of health, education and corrections workers who had received two vaccine doses over time, compared with workers in barely-mandated industries 4. The vertical lines represent the mandate announcement date (11 October 2021 for all three mandated groups), the first dose deadline for HCW and education workers (15 November 2021, whereas it was slightly earlier on 6 November 2021 for corrections workers) and the second dose deadline for HCW and education workers (1 January 2022, whereas it was 8 December 2021 for corrections workers) respectively.

Figure 4: Cumulative double-vaccination rate by industry



HCWs had the earliest and fastest rate of vaccine uptake, with a fast initial uptake once the nationwide vaccination roll-out began, followed by a gradual increase to a ‘steady state’ vaccination rate. This pattern is perhaps unsurprising given they were one of the earliest groups to gain access to the vaccine as part of the roll-out strategy to manage the initially limited vaccine supply. Recall that HCWs had ready access to the vaccine from March 2021, whereas the vaccine availability was rolled-out by age group categories for the general population, with it being widely accessible to all those aged 12 and over from September 2021. Moreover, we would expect health workers to have a higher propensity to vaccinate regardless of the mandates than the general population. By October 2021, when the vaccine mandate was announced, HCWs' double-vaccination rate had already reached just over 89%, and this increased gradually after the announcement to level off at about 95%. Visual inspection suggests there was not a discontinuous jump in the vaccination rate after the announcement of mandates, and the increase was part of an ongoing but slowing upwards trajectory.

Uptake among correction workers followed a similar trajectory as health workers, but the fast initial uptake began later from May 2021. This likely reflects that they also had early access to the vaccination, but the roll-out for this group started later, in May 2021. The slowing uptake in June likely reflects that the roll-out for this group was suspended in June 2021 in order to manage limited vaccine stocks, before resuming again in July 2021. Similar to health workers, there does not appear to be a discontinuity in the vaccination rate following the mandate announcement. By October, the double-vaccination rate had reached 86% before levelling off at about 95%.

The pattern for education sector workers is different, and is more similar to workers in the barely-mandated industries. Education workers did not have early access to the vaccine, which is likely reflected in the slow initial uptake followed by a sizable increase around August 2021, when the vaccination became more widely available to older age groups, followed by a larger increase around September 2021, when the vaccine became available to every aged 12 and over. Despite this later access to the vaccine, education workers had reached a double-vaccination rate of 82% by October 2021, with the rate levelling off at about 95%, which is very similar to the vaccination rate among health and corrections workers. The comparison with education and corrections workers suggests that the vaccination uptake over time, and particularly the pattern before the vaccine mandates were announced, is strongly linked to the availability of the vaccine rather than anticipatory effects.

Comparing HCWs with barely-mandated workers in Figure 4 does, however, reveal an issue for DiD analysis: the parallel trends assumption is violated. HCWs' early access to the vaccine resulted in much faster uptake among HCWs than barely-mandated workers in the pre-treatment period. Indeed, the results for a DiD estimate as detailed in Equation 1 provide a negative δ coefficient, suggesting the mandates actually decreased vaccine uptake among health workers (see Appendix A, Table A1). However, this is in line with Figure 4, as the vaccine rate among HCWs was considerably higher than among barely-mandated workers by the time the mandates were announced in October 2021, and thus had less room to increase after the announcement. In contrast, many barely-mandated workers would have only gained access to the vaccine in September 2021, and thus, their vaccination rates were still on a stronger upwards trajectory.

While it is difficult to overcome this parallel trends issue for this research question,[12] provided there were no anticipatory effects, the fact that the HCWs' double-vaccination rate had already reached just over 89% before the mandate was announced, and that it levelled off at about 95% suggests that the mandate would have, at the very most, increased vaccination rates by six percentage points among HCWs. Moreover, given HCWs' vaccination rates were still on an upwards trajectory when the mandates were announced, it is likely that the effect of the mandates would have been less than this upper bound six percentage points. In addition, the lack of a discontinuous jump in vaccine rates around the time of the announcement is telling. This contrasts with international research examining vaccine passes (rather than vaccine mandates) for France, Italy and, to a lesser extent, Germany (Oliu-Barton et al., 2022), as well as Lithuania (Walkowiak, Walkowiak, & Walkowiak, 2021). In these cases, there was a jump in vaccine rates after the vaccine pass was announced. Furthermore, vaccine rates in these countries were much lower before the announcement (less than 65% had received one dose at the time of the announcements in all of these countries), providing more room for vaccine passes in these countries to potentially increase vaccination rates than in the case of vaccine mandates in NZ.

7 Results: RQ2 - Healthcare workers labour market outcomes

We now turn to our second research question: did the vaccine mandates impact the labour market outcomes of unvaccinated healthcare workers? In particular, did they increase healthcare worker job separation rates? These questions are important in terms of workers' outcomes. They are also important in the context of ongoing HCW shortages experienced not only in NZ, but many countries.

[12] We considered the use of other comparison groups, but due to the early access to vaccines for health and corrections workers and a likely higher propensity to vaccine among all three groups of workers regardless of the mandates, it is difficult to overcome the parallel trends issue.

7.1 Tracking workers' outcomes over time

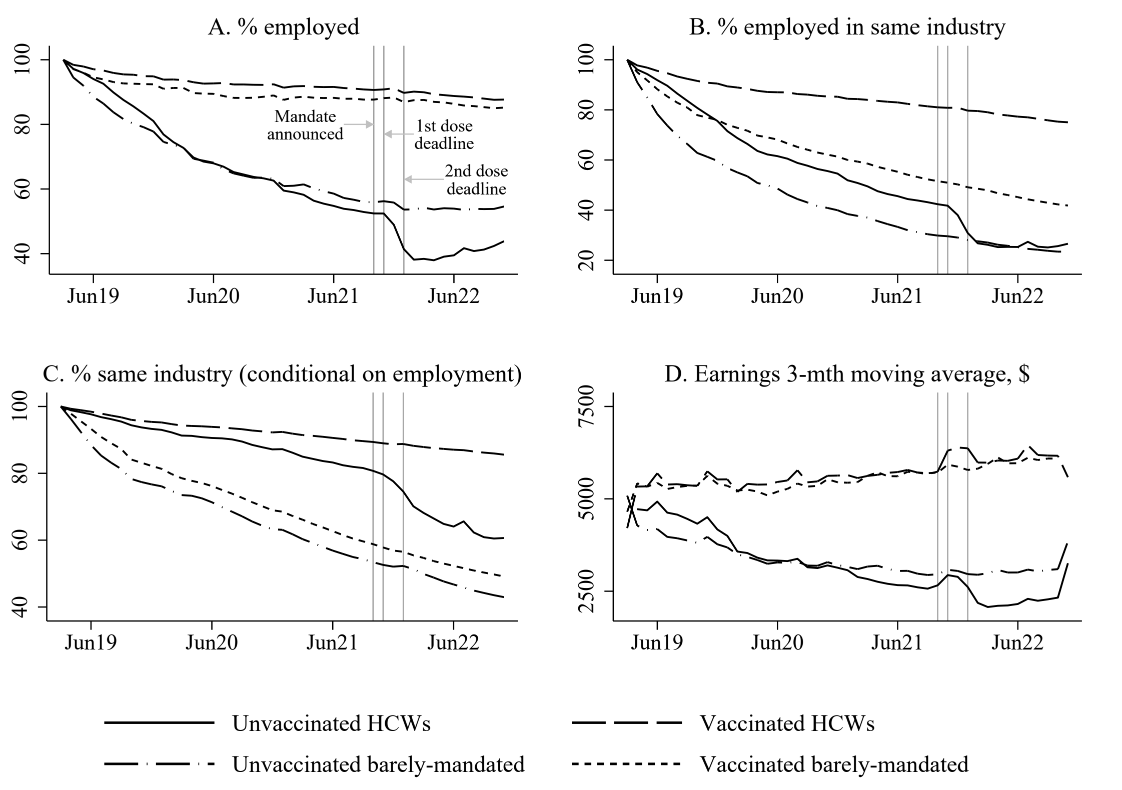
As described in Section 4.2, we track four groups of workers over time. We track HCWs who complied with the vaccine mandate (144,087 'vaccinated HCWs') and those who did not (12,330 'unvaccinated HCWs'). We also track barely-mandated workers who were vaccinated within the vaccine mandate timelines (although they were not subject to the mandates) (1,068,726 'vaccinated barely-mandated workers'), and barely-mandated workers who were not vaccinated within the mandate timelines (174,099 'unvaccinated barely-mandated workers').

Panel A of Figure 5 shows employment rates over time. By construction, these are 100% in March 2019 as we defined our population of interest at this date (see Section 4.2). The employment patterns are very different between vaccinated and unvaccinated HCWs even before the mandates were announced, with unvaccinated HCWs having lower employment rates over time. This is perhaps unsurprising given we know from Section 6.1 that vaccinated and unvaccinated have different characteristics - for example, unvaccinated workers tend to have lower earnings and therefore may have lower labour market attachment. Moreover, these differences seem to be related to vaccination status rather than industry of employment as the employment rate patterns for vaccinated HCWs and vaccinated barely-mandated workers, as well as unvaccinated HCWs and unvaccinated barely-mandated workers, are similar.

The employment rates of unvaccinated HCWs became to fall slightly faster than that of unvaccinated barely-mandated workers in the months leading up to the vaccine mandate announcement. This could be indicative of anticipatory effects. However, other evidence suggests that anticipatory effects were unlikely (e.g. a lack of media discussion of the possibility of mandates, as discussed in Section 4.1.3) and, in any case, it seems unlikely that individuals would leave their roles before they had to if they did not have another role to go to, unless there were extenuating circumstances. Indeed, a more likely explanation is that unvaccinated HCWs may have felt pressure and elevated workplace stress due to their vaccination status that was not felt to the same extent by unvaccinated barely-mandated workers. This conjecture is supported by qualitiative research which highlights that unvaccinated workers experiencing ostracism at work and resulting high levels of workplace stress (Dewar et al., 2024). In any case, this pre-announcement employment effect is minimal.

Little happened to the employment of unvaccinated HCWs immediately after the mandate was announced in October 2021. However, from November 2021, when the first dose requirement came into effect, the employment rate of unvaccinated HCWs dropped noticeably relative to those of unvaccinated barely-mandated workers. From early 2022, the employment rate of unvaccinated HCWs started to recover gradually, presumably as unvaccinated workers began new jobs in other non-mandated industries.

Figure 5: Tracking workers' labour market outcomes over time



Notes: The vertical lines at October 2021, November 2021 and January 2022 represent the vaccine mandate announcement date, first dose compliance deadline and second dose compliance deadline respectively.

In addition, the HCW mandate was lifted in late September 2022, towards the end of the time period examined, which would have allowed unvaccinated former HCWs to take up positions in the health industry again. However, as noted, there was no obligation for employers to reinstate them into their previous roles and, indeed, qualitative research suggests some unvaccinated HCWs had difficulties finding employment in the health industry even after the mandates were lifted (Dewar et al., 2024).

We now examine employment rates within the same industry (Figure 5, Panel B). For HCWs, this measures whether the individual remained employed within the healthcare industry. For barely-mandated workers, this is whether the individual was employed within the same 1-digit ANZSIC industry (as explained in Section 4.2). Vaccinated HCWs had the highest propensity to remain employed within the same industry, while unvaccinated barely-mandated workers had the lowest. Of most relevance is that there was a distinct drop in same-industry employment for unvaccinated HCWs following the first dose deadline that is not observed for any of the three other groups. Same-industry employment for unvaccinated HCWs did increase slightly in the last few months of the series, possibly reflecting the lifting of the mandate in late September 2022. However, the slight increase began before the mandate was lifted and may reflect that some HCWs were being redeployed within the health industry to roles that had no contact with health practitioners or the general public, and, therefore, were not covered by the mandate. The fact that not all HCWs were subject to the vaccine mandate (see Section 4.1) also explains why employment within the healthcare industry for unvaccinated workers does not fall to 0%.

Part of the reason for the lower same-industry employment among unvaccinated workers shown in Panel B of Figure 5 could be the lower employment rates among these workers (as shown in Panel A of Figure 5). Therefore Panel C shows same-industry employment conditional on being employed. The smaller gap between unvaccinated HCWs (barely-mandated workers) and vaccinated HCWs (barely-mandated workers) highlights that some of the differences in Panel B are due to employment rate differences. However, the same general pattern of a large post-mandate drop in health-industry employment among unvaccinated HCWs that is not observed for the other three groups of workers is evident. Once again, the fact that unvaccinated HCWs experienced a faster fall in same-industry employment conditional on being employed than the vaccinated HCWs in the months leading up to the mandate announcement could signal anticipatory effects, but more likely reflects that there was pressure on unvaccinated HCWs due to their vaccination status even before the mandates were announced, leading to somewhat elevated job separation rates among this group.

Panel D of Figure 5 tracks earnings, taking a three-period moving average to reduce fluctuations due to cyclical seasonality. Vaccinated HCWs and barely-mandated workers have similar earnings trends, which are higher than those of unvaccinated workers, which is consistent with their higher employment rates. Unvaccinated HCWs workers experienced an initial increase in earnings after the mandate was announced, followed by a sharp drop in earnings after the mandate announcement that was not experienced by the other groups of workers. The initial increase in earnings among unvaccinated HCWs likely reflects that many were receiving final pay cheques before leaving their jobs, which tend to be larger than a typical pay cheque due to factors such as the payment of outstanding holiday pay. However, average earnings of unvaccinated HCWs began to recover towards the end of the period, which likely reflects a combination of workers finding alternative employment and the mandate being lifted in late September 2022 so unvaccinated former HCWs could potentially return to the healthcare industry.

These descriptive trend graphs also provide further rationale for the use of a triple difference approach. This approach requires only one parallel trend to hold. Since the pairing of worker groups is arbitrary and mathematically equivalent, it does not matter which pairing the parallel trend holds for (Olden & Møen, 2022). That is, it can hold for unvaccinated HCWs and vaccinated HCWs, or unvaccinated HCWs and unvaccinated barely-mandated workers. The descriptive graphs show that the assumption of least one parallel trend holding is generally plausible, and it varies whether this is met through the unvaccinated HCWs and vaccinated HCWs comparison, or the unvaccinated HCWs and unvaccinated barely-mandated workers comparison. Since we are focussing on dynamic DDDs, the existence of pre-trends will be examined more systematically below in Section 7.2.

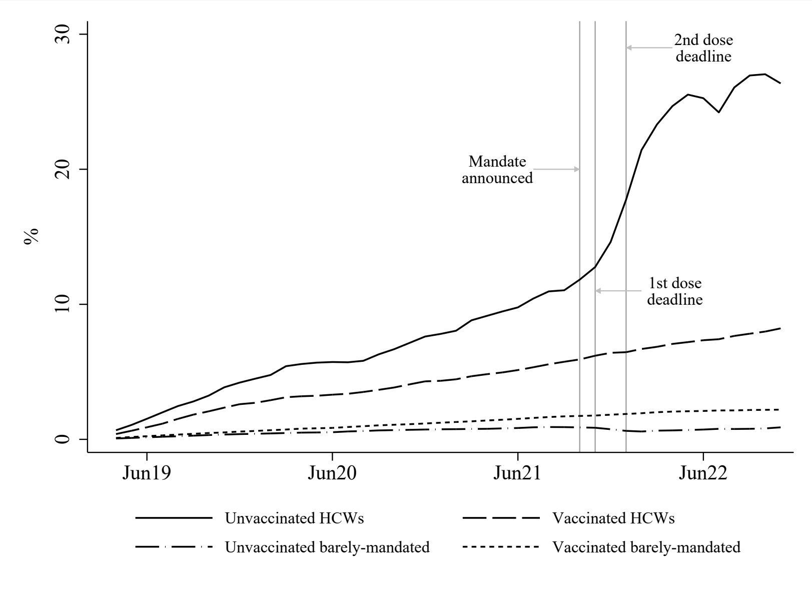
While Figure 5 examines descriptively the main outcome variables that we will undertake DDD analysis on, it focuses on HCWs propensity to remain in the health industry given the mandate. However, it is possible that even if the mandate resulted in worse labour market outcomes, including a lower rate of employment among unvaccinated HCWs in general, and in healthcare specifically, the roles left vacant by unvaccinated workers could have been filled via new entrants into the health industry. As discussed, given the large extent of shortages of HCWs not just in NZ but globally, that many health roles require years of training and experience, and that NZ's borders were largely closed during the period of the vaccine mandate (thus limiting off-shore recruitment), it seems unlikely that new entrants into the industry would have offset the loss of unvaccinated workers.

However, to examine this descriptively, Figure 6 looks at the rate at which vaccinated and unvaccinated barely-mandated workers switched to working in the health industry (conditional on employment), and the rate at which vaccinated and unvaccinated HCWs switched to barely-mandated industries. Prior to the mandates, unvaccinated HCWs had a somewhat higher propensity to leave the health industry and begin work in a barely-mandated industry than vaccinated HCWs. However, this difference increased markedly following the announcement of the vaccine mandate. There is little worker movement from barely-mandated industries to the health industry overall, and only a small amount of movement of unvaccinated barely-mandated workers to the health industry. Moreover, after the mandate announcement, this small amount of movement for unvaccinated barely-mandated workers slowed even further, as jobs in the health industry became largely closed off to them.

7.2 Triple difference: Estimating the role of mandates in HCWs' labour market outcomes

We now formally test the effect of mandates on the outcomes discussed descriptively in Section 7.1 above. Due to computational limitations, all estimates in this section are based on a 10% random sample of the population of interest equating to

Figure 6: Tracking workers' industry switching rates over time



Notes: The vertical lines at October 2021, November 2021 and January 2022 represent the vaccine mandate announcement date, first dose compliance deadline and second dose compliance deadline respectively.

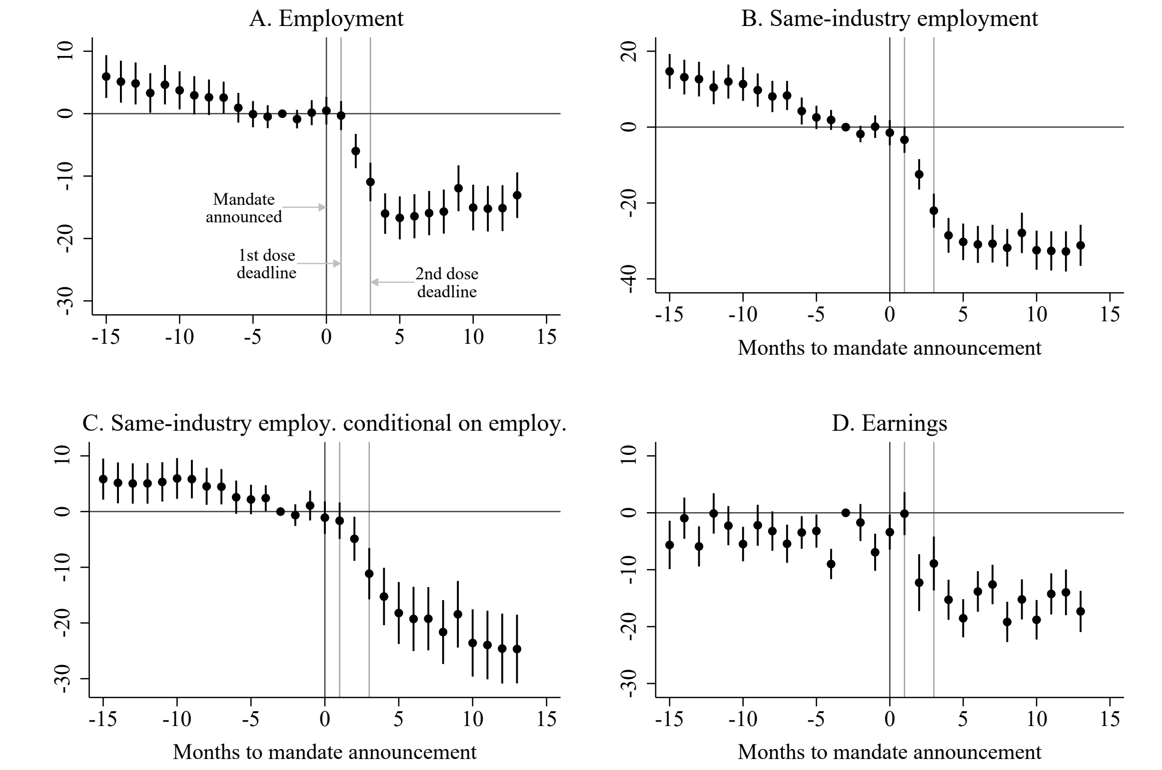
3,891,945 individual-month observations (a balanced panel of 134,205 individuals over 29 months).

Figure 7 plots the coefficient of interest (the triple interaction coefficient, γ_3, from Equation 3) as a percentage of the counterfactual. (Regression results in percentage points for employment, same-industry employment, same-industry employment conditional on employment, and dollars for earnings are available in Appendix B). Month zero is October 2021, when the mandate was announced, as indicated by the first vertical line. The two additional vertical lines indicate the deadlines by which mandated workers were required to have one and two vaccine doses (November 2021 and January 2022 respectively).

Panel A of Figure 7 presents employment rates. There are some significant differences in the employment rate of unvaccinated HCWs and the comparison group in the months before the mandate was announced. Moreover, because there was a general downward pre-trend the post-mandate difference may be somewhat overestimated, although the magnitude of these pre-trends are relatively small and are not statistically significant in the six months before the mandate announcement. Reassuringly, analysis for separate socioeconomic groups presented in Section 7.4 exhibit fewer pre-trends and the same general effects in the post-mandate period.

By the second month after the mandate was announced and the first month after the first dose deadline (December 2021), the employment rate of unvaccinated HCWs was lower than the comparison group. These post-announcement differences are statistically and economically significant. The employment rate is more than 17 percentage points lower - see Appendix B - or 15% of the counterfactual employment rate in some months.

Figure 7: Triple difference results: Change in outcome variable as percentage of the counterfactual



Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

The pattern for same-industry employment is similar to that of overall employment, with unvaccinated HCWs much less likely to remain employed in the health industry after the mandate was announced (Figure 7, Panel B). Unsurprisingly, the magnitude of the difference is larger than in the case of the overall employment rate, with the same-industry employment rate being up to 22 percentage points lower, or 33% of the counterfactual employment rate. The results for same-industry employment conditional on being employed are similar, although the magnitude of the effect is smaller (up to 17 percentage points or 25% of the counterfactual).

The earnings of unvaccinated HCWs is sometimes lower and statistically significant relative to the comparison group in the pre-announcement period. However, there is a noticeable drop in the earnings difference from the first month after the first dose deadline (December 2021). The earnings differential is statistically significant and negative in all months after the mandate deadline, and of economically significant magnitude (up to about \$1,476 lower earnings in a month or 19% of the counterfactual earnings).

In summary, these results suggest that the vaccine mandates had a negative effect on overall employment rates, rates of employment within the health industry and workers' earnings.

7.3 Robustness: Two-period triple difference

As a robustness check, we also estimate two-period triple difference regressions (presented in Appendix C). The estimates are consistent with those from the dynamic triple difference regressions (as presented in Appendix B). The vaccine mandate is estimated to result in an employment rate which is 14 percentage points lower or -14% of the counterfactual, a same-industry employment rate that is 21 percentage points lower or 27% of the counterfactual, and a same-industry employment rate conditional on employment that is 13 percentage points lower or -17% of the counterfactual. Earnings are estimated to be about \$700 lower or -11% of the counterfactual.

7.4 Heterogeneity analysis

The HCW vaccine mandate may have impacted different types of workers differently. For example, perhaps older unvaccinated HCWs were more likely to fall out of employment than younger unvaccinated HCWs, either because they had more difficulty transitioning to alternative employment, or because they were more likely to enter early retirement. To explore possible heterogeneity in the impact of the mandates, this section undertakes separate DDD analysis for different groups by gender, age, ethnicity, birthplace, deprivation level and income quartile. For brevity, we present only results for employment and earnings.

Gender

As mentioned, the pre-trends in the sub-group analysis tend to be smaller than in the overall analysis. Figure 8 shows that for men, there are no statistically significant differences in employment before the mandate announcement. For women, the pre-trends are small and not statistically significant in the six months before the mandate announcement. For both men and women, significant differences emerge one month after the first dose deadline. The magnitude of the effect of the mandates is larger for men than women. For men, the employment rate is up to 20 percentage points lower,

Figure 8: Gender: Triple difference results: Change in outcome variable as a percentage of the counterfactual

Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

or -19% of the counterfactual. For women, the employment rate is up to 14 percentage points lower, or up to -14% of the counterfactual. This is somewhat unexpected given women are more likely to be secondary income earners and, therefore, presumably less attached to the labour market. However, it could be that unvaccinated female HCWs were more able to transition to alternative employment than unvaccinated male HCWs.

For earnings, the effect of the mandate is clearer for women than men. Unvaccinated male HCWs tend to have lower earnings than the comparison group even in many of the months prior to the mandate announcement, although the post-announcement differences are larger and more of them are statistically significant. For women, there are few pre-announcement periods with statistically significant differences, and statistically significant differences in earnings emerge one month after the first dose deadline. However, consistent with the employment results, the change in post-announcement earnings is larger for men than women. For men, earnings are up to \$2,636 lower, or -26% of the counterfactual. For women, earnings are up to \$1,177 lower, or -19% of the counterfactual.

Age

Estimating separate results for younger (aged 20-39) and older (aged 40-60) workers shows that there are no statistically significant pre-announcement differences for younger workers, and only a few for older workers (Figure 9). Employment rates for both younger and older workers fell after the mandate announcement. In terms of the magnitude of the effect, younger workers have a somewhat smaller fall in employment (up to -16 percentage points or -16% of the counterfactual) than older workers (up to -19 percentage points or -18% of the counterfactual). In addition, the employment rates of younger workers recover more over time, perhaps indicating they were better able to transition into alternative employment, or that older workers had lower labour market attachment (e.g. more likely to enter early retirement).

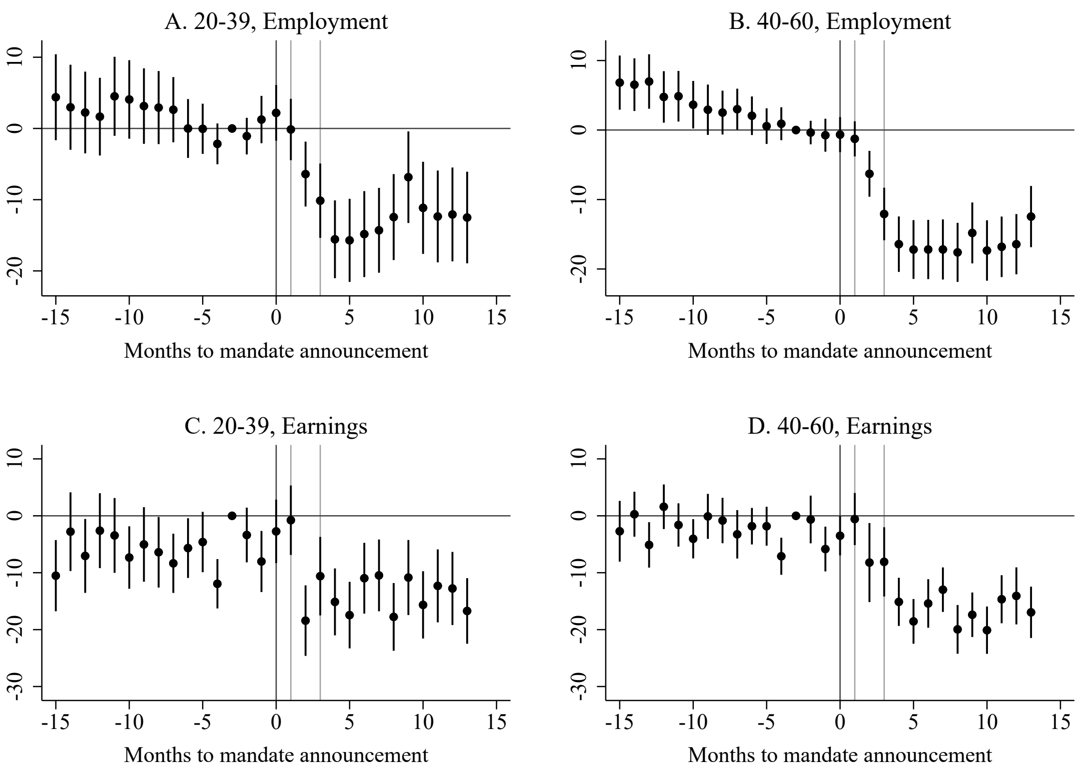
In terms of earnings (Figure 9), while there are some statistically significant pre-announcement differences, there is a marked drop in earnings from one month after the first dose deadline for both younger and older workers. Once again, the effect was somewhat larger for older workers (up to -\$1,791 or -20% of the counterfactual) than younger workers (up to -\$1,384 or -18% of the counterfactual).

Ethnicity

Examining separate results for European, Māori and Pacific workers (Figure 10), for employment rates, there are no statistically differences for any of these ethnic groups prior to the mandate announcement. After the mandate announcement, unvaccinated European and Māori HCWs experienced a drop in employment relative to the comparison groups. The magnitude of the effects of the mandates on employment among unvaccinated European and Māori HCWs is similar (a fall in employment of up to 22 percentage points for Europeans and 20 percentage points for Māori, equating to about -20% of the counterfactual for both). The Pacific worker results are different, with no statistically significant effects on employment of the mandates.

It is unclear why the unvaccinated Pacific HCWs did not experience a statistically significant drop in employment rates. Same-industry employment results (not shown) have a similar pattern of large, negative effects for unvaccinated European and Māori HCWs but no significant effects for Pacific HCWs. This suggests that the Pacific employment rate results were driven by unvaccinated HCWs remaining in the health industry rather than having higher transition rates to other non-mandated industries. Thus, it could be that Pacific HCWs were more likely to work in roles that were not covered by the mandate (that is, they were not health practitioners and did not have

Figure 9: Age: Triple difference results: Change in outcome variable as a percentage of the counterfactual



Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

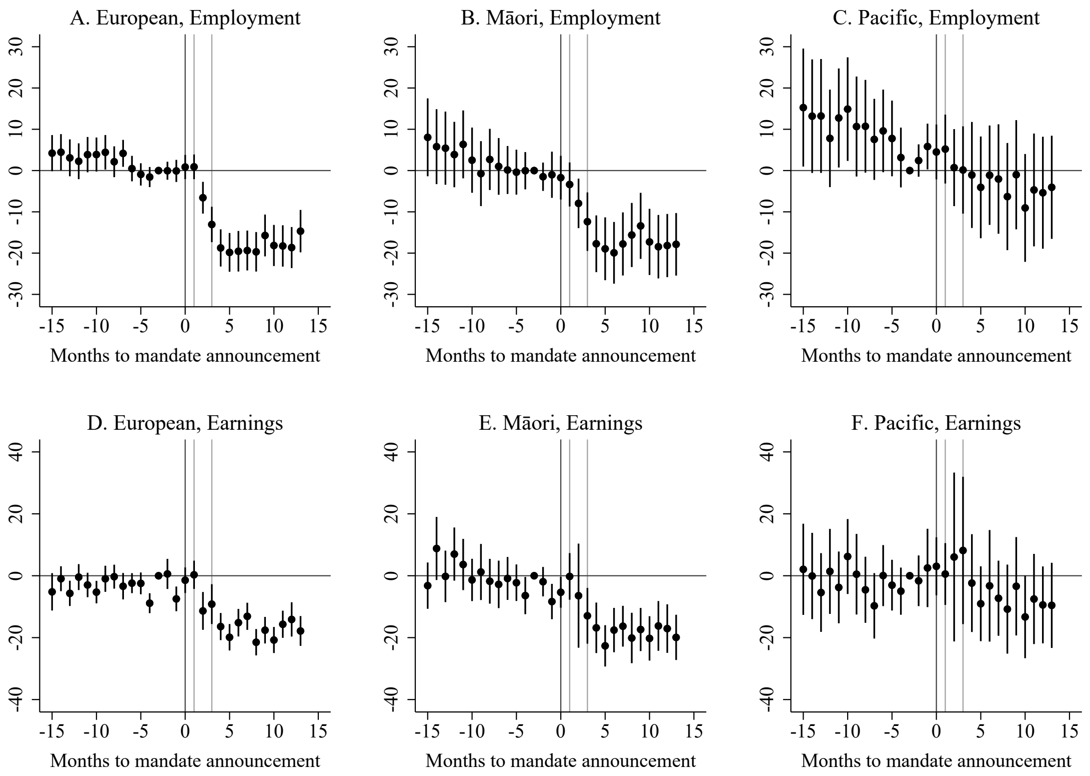
roles that involved being within two metres of a health practitioner or member of the public).

In terms of earnings, the mandates had a negative effect on the earnings of European and Māori unvaccinated HCWs, with the effect for these two groups being of similar magnitude (up to -\$1,802 or 21% of the counterfactual for Europeans and -\$1,526 or -23% for Māori). In line with the employment results, there is much less of a clear drop in earnings after the mandate announcement for unvaccinated Pacific HCWs, and none of the differences are statistically significant.

Born in NZ

Comparing those who were born in NZ with those who were not, Figure 11 shows that both groups have a large drop in employment after the mandate was announced. The magnitude of the drop in employment is larger among unvaccinated HCWs who

Figure 10: Ethnicity: Triple difference results: Change in outcome variable as percentage of the counterfactual

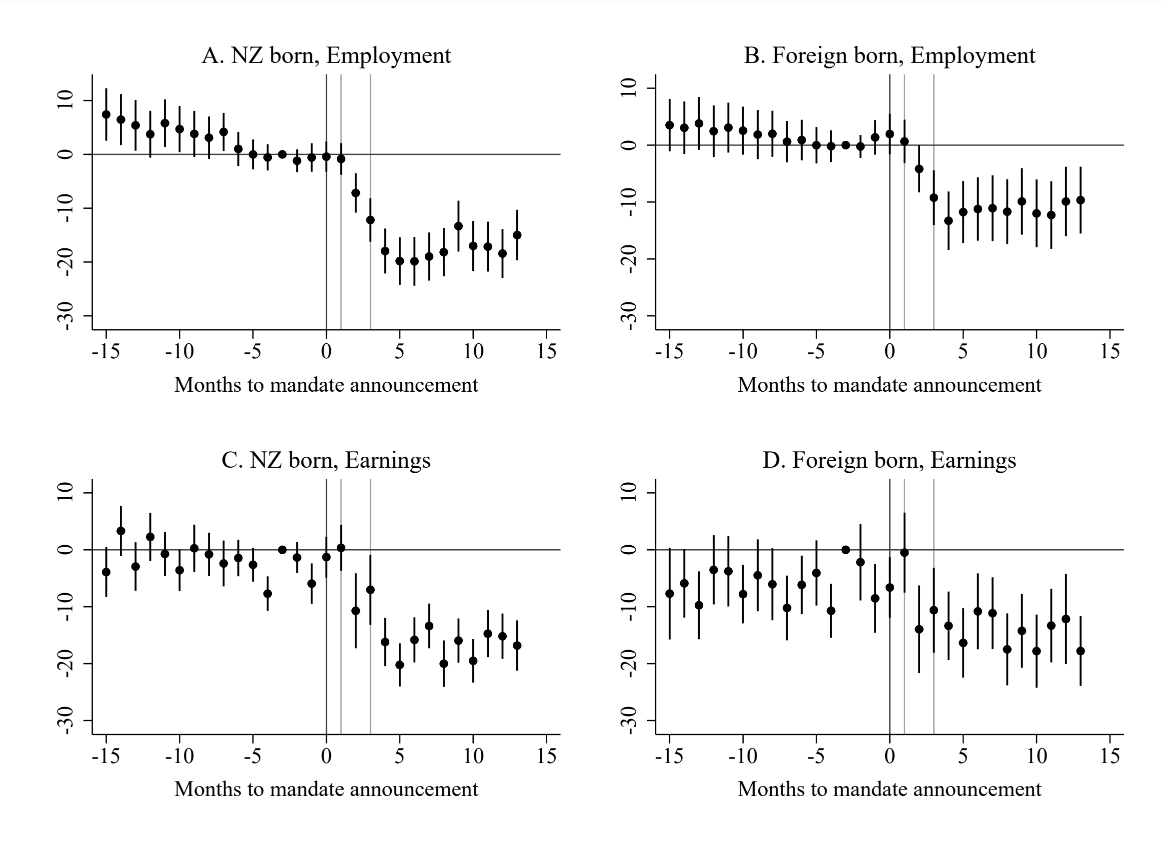


Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

were born in NZ (-21 percentage points or -20% of the counterfactual) than those who were born overseas (-13 percentage points or -13% of the counterfactual). This larger effect for those born overseas is also true of same-industry employment (not shown). Thus, it appears that foreign-born HCWs more readily transitioned to employment in non-mandated industries, but also that they may have had roles within the health industry that were less likely to be covered by the mandate.

In terms of earnings, the effect of the mandate is clearer for unvaccinated NZ-born HCWs than those born overseas due to some pre-announcement negative earnings differences for those born overseas. However, both experience a drop in earnings after the mandate announcement. For unvaccinated NZ-born HCWs, the mandate resulted in an earnings drop of up to $1,593 (or -20% of the counterfactual). For unvaccinated foreign-born HCWs, the mandate resulted in an earnings drop of $1,411 (or -18% of the counterfactual).

Figure 11: NZ born: Triple difference results: Change in outcome as percentage of the counterfactual



Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

Deprivation index

For both medium-to-high and low deprivation unvaccinated HCWs, the mandate resulted in a drop in employment. The effect is larger for those who had low measured deprivation (-16 percentage points or -16% of the counterfactual) than those with medium-to-high levels of deprivation (-21 percentage points or -20% of the counterfactual). The results for same-industry employment are of very similar magnitude for both groups (not shown). This suggests that those with low levels of deprivation were less likely to transition to alternative employment rather than being less likely to work in a health industry role that was not covered by the mandate. This may be because those with higher levels of deprivation had to find alternative employment whereas those with low levels of deprivation were able to choose not to do so and exit employment instead.

Unvaccinated HCWs from both deprivation groups also experienced a drop in earn-

Figure 12: NZ born: Triple difference results: Change in outcome as percentage of the counterfactual

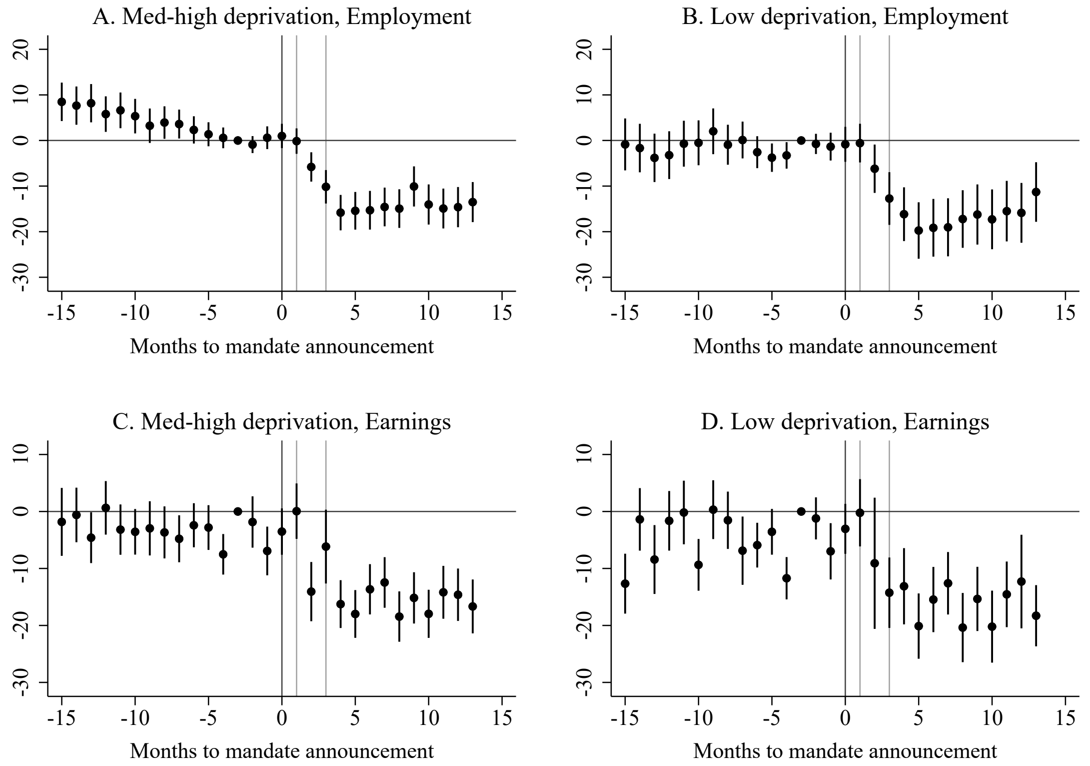


Figure 13: Deprivation: Triple difference results: Change in outcome as percentage of the counterfactual

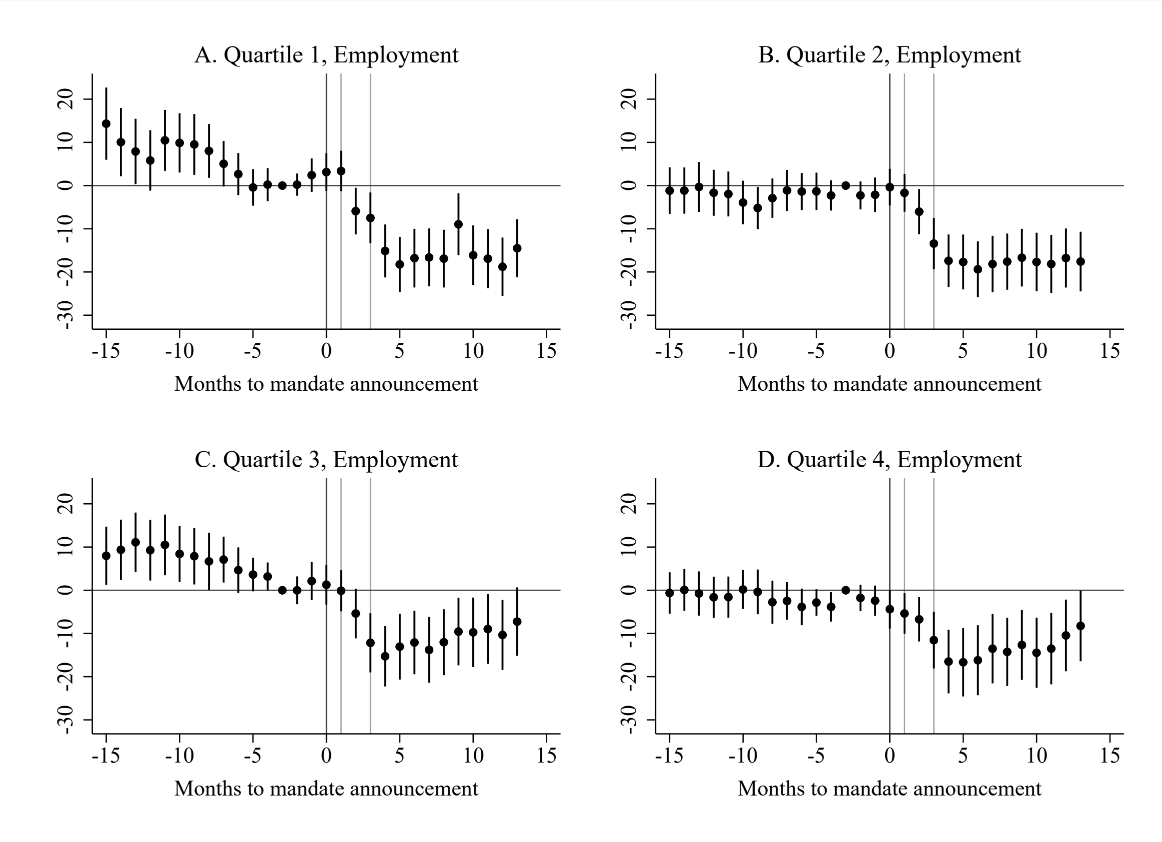
Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

ings after the mandate announcement. The effect was also similar in magnitude, with a \$1,294 drop (-18% of the counterfactual) for medium-to-high deprivation unvaccinated HCWs, and a \$1,929 drop for low deprivation unvaccinated HCWs (-20% of the counterfactual).

Income quartiles

We now undertake separate analysis by income quartiles. For all four quartiles, the mandate had a negative employment effect. However, the magnitude of the effects and the patterns over time differ. For unvaccinated HCWs in the lowest two income quartiles, the employment effect is larger than for the higher quartiles (-19% for quartiles 1 and 2 versus -15% and -16% of the counterfactual for quartiles 3 and 4). In addition, the employment rates of quartiles 3 and 4 begin to recover over time, while this is not observed for quartiles 1 and 2. This could reflect that those on higher incomes can more readily transition to roles in non-mandated industries. This would accord with literature that finds that workers with lower incomes and lower skills and/or qualifications are less resilient to adverse events, such as recessions (e.g., Shibata, 2021) and health shocks (e.g., García-Gómez et al., 2013).

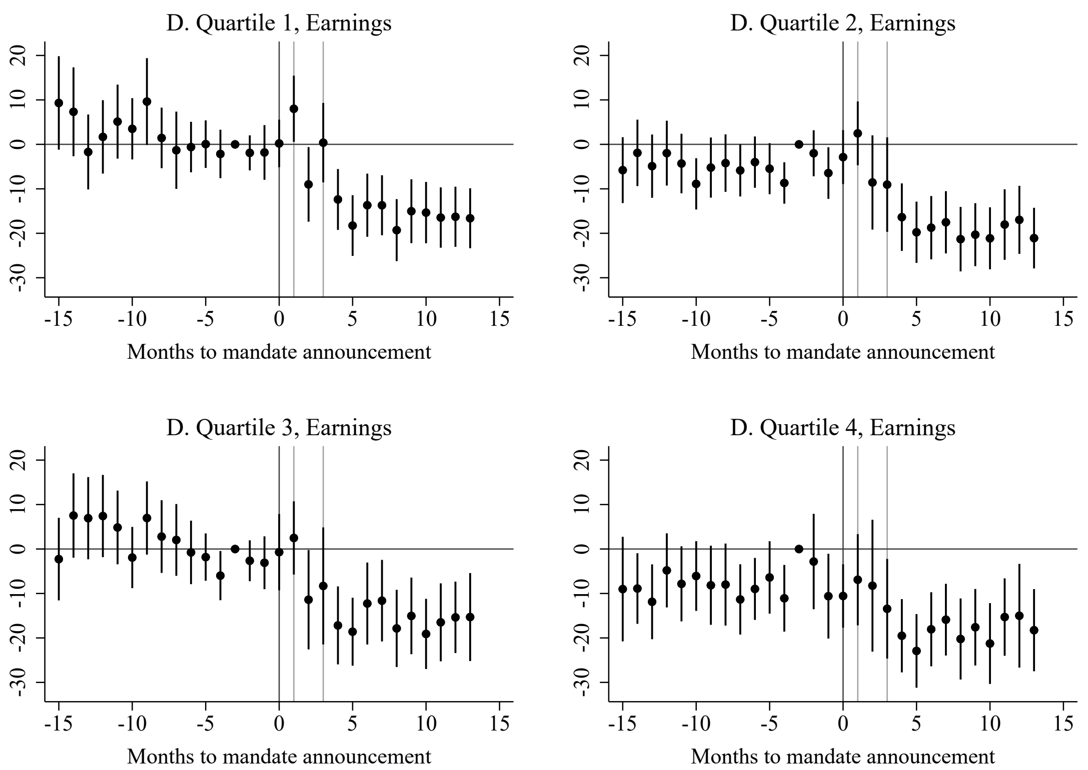
Figure 14: Income: Triple difference results: Change in employment as percentage of the counterfactual



Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

In terms of earnings, the vaccine mandate had a negative effect on the earnings of unvaccinated HCWs in all four income quartiles. The magnitude of the effect in terms of the dollar fall in earnings increases as income increases (from -$737 for income quartile 1 to -$3,358 for income quartile 4). However, this is due to differences in income levels across the quartiles as the effects in terms of a comparison with the counterfactual are of similar magnitude (-19% for quartiles 1 and 3, -21% for quartile 2 and -23% for quartile 4).

Figure 15: Income: Triple difference results: Change in earnings as percentage of the counterfactual



Notes: Estimates of the triple-interaction coefficient from Equation 3 with socioeconomic controls, as a percentage of the counterfactual. The vertical lines at time 0, time 1 and time 3 represent the vaccine mandate announcement date and 1st and 2nd dose compliance deadline respectively. The vertical bars around the point estimates are the 95% confidence intervals.

8 Policy discussion

Our findings suggest that vaccine mandates did little to increase the uptake of COVID-19 vaccinations given that uptake was already high in general, and particularly high among workers covered by the mandates. Moreover, they had a negative effect on the labour market outcomes of unvaccinated HCWs, which not only had consequences for the individuals involved, but also likely contributed to ongoing skills shortages in the health industry.[13] For future pandemic planning, this suggests that vaccine mandates should be used judiciously.

While beyond the scope of our analysis, another consideration is whether mandates could have the unintended consequence of crowding out vaccination willingness, with potential spillover effects to other vaccinations (Dubé et al., 2021). For example, the experimental economics literature finds that people are averse to control, with agents exerting more effort when the principal implements a high-trust, low-control system and less effort under a low-trust, high-control system (e.g., Burdin, Halliday, & Landini, 2018; Ziegelmeyer, Schmelz, & Ploner, 2012).

In terms of COVID-specific evidence, a representative panel survey in Germany found that mandates "substantially increase opposition to vaccination" (Schmelz & Bowles, 2022, p.1). This survey, with three waves starting in May 2021 (when the double-vaccination rate in Germany was less than 7%), found that few respondents were consistently opposed to being vaccinated if vaccinations were encouraged but remained voluntary (3.3%). However, a much higher share were consistently opposed to being vaccinated if vaccinations were mandatory (16.5%) (Schmelz & Bowles, 2022). Furthermore, the opposition to voluntary vaccinations was more transient - many of those who opposed in one survey wave changed their view in support of voluntary vaccination in later waves. In contrast, the opposition to mandatory vaccinations was more stable - the majority of those who opposed in one wave remained opposed in later waves. In addition, those opposed to mandated vaccinations had similar demographic and socioeconomic characteristics as the overall German population. However, what differentiated them was their level of trust in public institutions, their beliefs about vaccine efficacy, and whether they viewed mandated vaccinations as a restriction on their freedom. Thus, vaccine mandates may negatively impact people's sense of civic duty and the feel-good factor associated with "doing the right thing". Gibson (2022a) also highlights that an unexpected cost of the COVID-19 pandemic may be erosion

[13]It would have been useful to additionally examine the impact on patient outcomes of the mandate policy. This could have been possible by analysing whether facility-level outcomes differed by the share of workers who left a particular facility due to the mandates. Unfortunately, an individual's place of employment and the health facility where a patient received treatment cannot be linked in the IDI. This is because the tax data assigns workplaces an employer ID, and health data assigns treatment facility IDs, but there is no way to link the two.

of public confidence in all vaccines, which is partly driven by inflated claims about COVID-19 vaccine efficacy creating unrealistic expectations among the public about what the vaccines could achieve. Gibson (2023) further argues that public misunderstanding of COVID-19 vaccine trials may have contributed to NZ's adoption of vaccine mandates, despite the costs of doing so outweighing the benefits (Lally, 2021).

Another aspect to consider in terms of policy inferences is the NZ context and environment when the mandates were introduced. Whether vaccine mandates will be a useful tool going forward will largely depend on whether voluntary compliance will be as high in future pandemics as it was at the time of the mandate introduction in 2021. The high voluntary vaccination rate was likely driven by a combination of factors, including a generally strong sense of civic duty and high levels of trust in the government, as well as other "softer" policies to encourage vaccination, such as vaccine passes to access non-essential buisnesses/services, vaccination rate targets to end lockdowns, mass vaccine events and so forth. Our analysis suggests that when voluntary vaccination rates are high, the benefits of mandates are limited, and are likely outweighed by the spillover costs in terms of worsening health workforce shortages. However, it remains an open question as to whether these results would hold in circumstances where voluntary vaccination rates are lower. Indeed, international research on the introduction of vaccine passes in jurisdictions where vaccination rates were much lower than at the time of NZ's introduction of vaccine mandates suggests that such measures do contribute to increasing vaccination rates.

9 Conclusion

This paper examines the effect of workforce vaccine mandates on vaccination uptake and healthcare workers' (HCWs') labour market outcomes. We use linked population-wide administrative data from New Zealand, which includes a comprehensive national vaccination register linked to tax records to identify employment outcomes.

We employ a difference-in-differences approach to isolate the effects of workforce vaccination mandates from the effects of the NZ government's population-wide initiatives to boost vaccination rates, particularly vaccine passes to access non-essential businesses/services. However, no comparison group could be found where the parallel trends assumption held due to HCWs' early access to vaccinations. However, vaccination rates were already very high among mandated workers when the mandates were announced, leaving little room for vaccination rates to increase. Moreover, unlike international studies examining vaccine passes, there is no discontinuous jump in vaccination rates following the mandate announcement.

We additionally apply a dynamic triple difference approach (DDD) to examine healthcare workers' labour market outcomes, comparing unvaccinated HCWs with vaccinated HCWs and vaccinated and unvaccinated workers in industries that were not covered by workforce mandates. We find that the mandates negatively impacted on unvaccinated workers' overall employment rates, their rates of employment within the health industry and their earnings. While some groups, such as higher-income workers, saw some recovery in their labour market outcomes over time, the negative effects persisted for most groups of workers throughout the 13-month post-announcement period.

Overall, the results suggest that in the context of already-high vaccination rates, workforce vaccine mandates may not have provided much benefit in terms of increasing vaccination rates among mandated workers. Moreover, they came at a cost in terms of HCWs' labour market outcomes, which may have had wider negative consequences in terms of the supply of healthcare workers in an area where skills shortages were already an issue.

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A Difference-in-differences: Estimating the role of mandates in vaccination uptake

We estimate two-period DiD regressions to evaluate the extent to which the COVID-19 vaccination mandates increased vaccination uptake across HCWs, correction workers, and education workers, separately. The comparison group comprises workers in barely-mandated industries. Table A1 presents the results. As mentioned in Section 5.1, the coefficient of interest in Equation 1 is δ (column (5) of Table A1).

Table A1 reveals a negative and significant effect of the COVID-19 vaccination mandates on vaccination uptake across all three mandated groups. For HCWs, the COVID-19 vaccination mandate led to a 28.3% decrease in vaccination uptake relative to barely-mandated workers. For corrections workers, the decrease was 12.5%, while for education workers, the decrease was 2.3%. All effects are highly significant and are robust to the inclusion of demographic and socioeconomic controls.

Table A1: Difference-in-differences estimating the effect of COVID-19 mandates on vaccination update

(1) Treatment Group	(2) Comparison Group	(3) Treatment Indicator	(4) Post-period Indicator	(5) Treatment * Post
HCWs	Barely mandated workers	0.345*** (0.001)	0.419*** (0.001)	-0.283*** (0.001)
Corrections Workers	Barely mandated workers	0.170*** (0.004)	0.284*** (0.000)	-0.125*** (0.006)
Education Workers	Barely mandated workers	0.073*** (0.001)	0.419*** (0.001)	-0.023*** (0.002)

Notes: This table presents the difference-in-differences regression results from Equation 1 for HCWs, corrections workers, and education workers, respectively. Column 3 presents the coefficient on the treatment indicator. Column 4 presents the coefficients on the post-period indicator. Column 5 presents the coefficient on the interaction between the treatment and post-period indicators. Standard errors are in parentheses. Asterix represents statistical significance at conventional levels, where * if $p < 0.10$, ** if $p < 0.05$, and *** if $p < 0.01$.

As discussed in Section 6.2, these negative estimates are a consequence of the vaccination time trends presented in Figure 4. Since mandated workers, particularly HCWs, had early access to the vaccine and, thus, a much faster vaccination uptake in the pre-treatment period, there was little room for mandate workers to increase their vaccination uptake after the mandates were announced, whereas barely-mandated workers had more room to increase uptake in the post-period. That is, the results are a consequence of the parallel trends assumption being violated.

B Dynamic triple difference regression results

Table B1: Dynamic triple difference regressions

		(1) Employment	(2) Same-industry employment	(3) Same-industry employment conditional on employment	(4) Earnings
		(Δ employ. rate)	(Δ employ. rate)	(Δ employ. rate)	(Δ $)
Vaccinated * HCW * Post-period					
Months to mandate announcement	-15	0.049***	0.087***	0.042***	-325.13***
		(0.015)	(0.014)	(0.013)	(124.87)
	-14	0.043***	0.077***	0.037***	-47.83
		(0.014)	(0.014)	(0.013)	(93.03)
	-13	0.04***	0.073***	0.035***	-346.99***
		(0.014)	(0.014)	(0.013)	(105.68)
	-12	0.028**	0.061***	0.035***	-6.02
		(0.014)	(0.013)	(0.013)	(92.44)
	-11	0.039***	0.068***	0.036***	-116.48
		(0.014)	(0.013)	(0.012)	(90.52)
	-10	0.032**	0.064***	0.039***	-350.97***
		(0.013)	(0.013)	(0.012)	(98.68)
	-9	0.025*	0.055***	0.038***	-109.45
		(0.013)	(0.013)	(0.012)	(91.87)
	-8	0.022*	0.045***	0.03***	-165.82*
		(0.012)	(0.012)	(0.011)	(91.02)
	-7	0.022**	0.046***	0.029***	-347.25***
		(0.011)	(0.011)	(0.01)	(109.31)
	-6	0.008	0.024**	0.017*	-191.63**
		(0.01)	(0.01)	(0.01)	(80.82)
	-5	-0.001	0.014	0.014	-174.03**
		(0.009)	(0.009)	(0.009)	(80.87)
	-4	-0.004	0.011	0.015**	-572.29***
		(0.008)	(0.008)	(0.007)	(86.07)
	-3	0	0	0	0
		(0)	(0)	(0)	(0)
	-2	-0.008	-0.01*	-0.004	-96.58
		(0.007)	(0.006)	(0.006)	(93.74)
	-1	0.001	0.001	0.007	-425.02***
		(0.009)	(0.008)	(0.008)	(101.98)
	0	0.004	-0.008	-0.007	-186.18**
		(0.01)	(0.009)	(0.009)	(85.6)
	1	-0.003	-0.018**	-0.01	-8.8
		(0.01)	(0.01)	(0.01)	(108.54)
	2	-0.056***	-0.075***	-0.03**	-904.77***
		(0.013)	(0.012)	(0.013)	(188.18)
	3	-0.105***	-0.145***	-0.074***	-506.56***
		(0.015)	(0.015)	(0.016)	(137.48)
	4	-0.164***	-0.203***	-0.104***	-971.53***
		(0.017)	(0.017)	(0.018)	(114.04)
	5	-0.173***	-0.217***	-0.127***	-1458.86***
		(0.018)	(0.018)	(0.02)	(134.5)
	6	-0.168***	-0.219***	-0.134***	-882.02***
		(0.018)	(0.018)	(0.021)	(116.03)
	7	-0.162***	-0.214***	-0.132***	-845.15***
		(0.018)	(0.018)	(0.02)	(118.53)
	8	-0.159***	-0.222***	-0.152***	-1425.49***
		(0.018)	(0.018)	(0.021)	(134.27)
	9	-0.115***	-0.181***	-0.123***	-991.7***
		(0.018)	(0.018)	(0.02)	(117.06)
	10	-0.15***	-0.222***	-0.166***	-1475.77***
		(0.019)	(0.018)	(0.022)	(139.02)
	11	-0.151***	-0.22***	-0.167***	-956.95***
		(0.019)	(0.018)	(0.022)	(123.93)
	12	-0.15***	-0.219***	-0.171***	-914.84***
		(0.019)	(0.018)	(0.022)	(134.23)
	13	-0.126***	-0.201***	-0.17***	-1332.95***
		(0.018)	(0.018)	(0.022)	(141.96)
Unvaccinated		Yes	Yes	Yes	Yes
HCW		Yes	Yes	Yes	Yes
Unvaccinated*HCW		Yes	Yes	Yes	Yes
Post-period		Yes	Yes	Yes	Yes
Unvaccinated * Post-period		Yes	Yes	Yes	Yes
HCW * Post-period		Yes	Yes	Yes	Yes
Socio-economic controls		Yes	Yes	Yes	Yes
Individual-month observations		3,891,945	3,891,945	3,891,945	3,891,945

Notes: This table presents the dynamic difference-in-differences regression results from Equation 3. Standard errors are in parentheses. Asterix represents statistical significance at conventional levels, where * if $p < 0.10$, ** if $p < 0.05$, and *** if $p < 0.01$.

C Two-period triple difference regression results

Table C1: Two-period triple difference regressions

	(1) Employment (Δ employ. rate)	(2) Same-industry employment (Δ employ. rate)	(3) Same-industry employment conditional on employment (Δ employ. rate)	(4) Earnings (Δ $)
Unvaccinated	-0.112***	-0.083***	-0.023***	-830.45***
	(0.003)	(0.004)	(0.005)	(25.71)
HCW	0.041***	0.231***	0.221***	612.62***
	(0.002)	(0.003)	(0.003)	(33.73)
Unvaccinated * HCW	-0.024*	-0.073***	-0.019	-369.90***
	(0.013)	(0.015)	(0.013)	(97.29)
Post-period	-0.012***	-0.126***	-0.133***	453.10***
	(0.001)	(0.001)	(0.001)	(6.30)
Unvaccinated * Post	-0.039***	0.004	0.003	-382.02***
	(0.003)	(0.003)	(0.003)	(16.71)
HCW * Post-period	-0.011***	0.068***	0.093***	29.32*
	(0.002)	(0.002)	(0.002)	(17.25)
Unvaccinated * HCW * Post-period	-0.140***	-0.210***	-0.130***	-700.32***
	(0.012)	(0.013)	(0.014)	(73.58)
Socioeconomic controls	Yes	Yes	Yes	Yes
Individual-month observations	3,891,945	3,891,945	3,891,945	3,891,945

Notes: This table presents the two-period difference-in-differences regression results from Equation 2. Results for the outcome of interest of employment, same-industry employment, same-industry employment conditional on employment and earnings are presented in Columns 1, 2, 3 and 4 respectively. Standard errors are in parentheses. Asterix represents statistical significance at conventional levels, where * if $p < 0.10$, ** if $p < 0.05$, and *** if $p < 0.01$.

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