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Vaccine mandates on childcare entry without conscientious objection exemptions: A quasi-experimental panel study

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ABSTRACT

Objectives: Examine the effect of No Jab No Play policies, which linked vaccine status to childcare service entry without allowing for personal belief exemptions, on immunisation coverage.
Study design: Immunisation coverage rates from the Australian Immunisation Register were linked to regional level covariates from the Australian Bureau of Statistics between January 2016 and December 2019. Differential timings of policy rollouts across states were used to assess changes in coverage with the implementation of policies with generalised linear models. Quantile regression and subgroup analysis were also conducted to explore the variation in policy responses.
Results: Baseline mean vaccination rates in 2016 were 93.4% for one-year-olds, 91.2% for two-year-olds and 93.2% for five-year-olds. Increases in coverage post-policy were significant but small, at around 1% across age groups, with larger increases in two and five-year-olds. Accounting for aggregate time trends and regional characteristics, implementation of the policies was associated with improved full immunisation coverage rates for age one (post-year 1: 0.15% [95 %CI–0.23; 0.52]; post-year 2: 0.56% [95 %CI 0.05; 1.07]), age two (post-year 1: 0.49 [95 %CI: 0.00; 0.97]; post-year 2: 1.15% [95 %CI: 0.53; 1.77], and age five (post-year 1: 0.38% [95 %CI 0.08; 0.67]; post-year 2: 0.71% [95 %CI 0.25; 1.16]. The policy effect was dispersed and insignificant at the lowest quantiles of the distribution of immunisation coverage, and smaller and insignificant in the highest socioeconomic areas.
Conclusion: Findings suggest that No Jab No Play policies had a small positive impact on immunisation coverage. This policy effect varied according to prior distribution of coverage and socio-economic status. Childcare access equity and unresponsiveness in high socioeconomic areas remain concerns.

1. Introduction

Australian federal and state level governments have introduced a series of policies that made receipt of financial benefits and access to childcare services conditional on keeping up to date with the childhood vaccination schedule [1]. This policy shift is consistent with international movement towards more stringent vaccine mandates that make benefits and services contingent on childhood vaccine status [2]. Public health interventions to increase childhood vaccination have increasingly used access to childcare to nudge parents towards vaccine uptake. Most interventions globally are quasi-mandatory and allow for nonmedical exemptions to these requirements; however, recently, vaccine mandates in California, Australia, France, and Italy have adopted a more stringent approach that either never allowed or eliminated conscientious objection exemptions [3–5].

Linking government benefits to vaccine status without non-medical exemptions has been found to have broad support amongst parents of young children in Australia [6]. Globally there has been considerable debate about the fairness and effectiveness of mandatory policies and particularly policies where access to childcare is conditional on adherence to vaccine schedules [7,8]. The emerging literature on mandatory vaccine policies in Australia, and elsewhere, has started to evaluate the impact of these mandates that employ behavioural conditionality. National policy No Jab No Pay (1st January 2016), which eliminated nonmedical exemptions for vaccine requirements for government benefits, has received recent attention in the literature [1,9–11]. These studies have showed an overall improvement in coverage, although the policy effects varied by area socioeconomics, baseline coverage, states or territory, and vaccine types [1,9,10,12]. However, isolating the policy effect of vaccine mandates on childcare from other

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interventions and accounting for untreated counterfactual outcomes remain a limitation.

The state-level No Jab No Play (NJNP) policies, which linked vaccination status to enrolment in childcare, pre-school, or kindergarten without allowing conscientious objection exemptions, have been rolled out at different times in different Australian states. The policy has been implemented in Victoria (VIC) and Queensland (QLD) (at service provider discretion) in January 2016, New South Wales (NSW) in January 2018, and Western Australia (WA) in July 2019. Other states and territories did not commence NJNP policies during the study period, including South Australia (SA) (adopted NJNP in August 2020), Tasmania (TAS), Australian Capital Territory (ACT), and Northern Territory (NT) (see Fig. 1 for the timeline of the policy enforcement in Australia). These states and territories did not yet require completion of the childhood vaccine schedule or a recognised vaccine catch-up schedule to attend childcare services. The variation in the timing of the policy rollout allowed for a quasi-experimental design, with the controls for temporal aggregate trends and regional differences between intervention (NSW, WA) and control groups (SA, TAS, ACT, NT), to obtain an appropriate counterfactual to estimate a causal policy effect. There has been limited attempt to evaluate the impact of NJNP by making use of a controlled before-and-after quasi-experiment design.

This study investigates the effect of state-level NJNP policies on childhood immunisation coverage in Australia. The national longitudinal data that incorporates intervention-and-control and before-and-after outcomes enables the identification of the causal effect of childcare entry mandates. The use of variation in the timing of the rollout allows for the disentanglement of national policies from NJNP. The study focused on intervention outcomes in NSW and WA to compare with counterfactual outcomes in control states, while accounting for aggregate trends, regional characteristics, and systematic difference between intervention and counterfactual groups. Standard regressions were used to assess mean policy effects, whilst quantile regressions were employed to test the differential impacts of NJNP in areas with different prior coverage. Policy effect variations were also investigated by socioeconomic status to gauge inequality implications of the policy. Several sensitivity analyses were performed.

2. Methods

2.1. Data

Data on childhood immunisation coverage are drawn from the Australian Immunisation Register (AIR) and linked with regional characteristics from the Australian Bureau of Statistics (ABS) census at the statistical area 3 (SA3) level between January 2016 and December 2019. The AIR is a national register that documents vaccination records for people of all ages in Australia. The data contain quarterly vaccination rates at the SA3 level at the childhood vaccine schedule milestone ages of one (12–15 months), two (24–27 months) and five (60–63 months), for Diphtheria, tetanus, pertussis (DTP), Polio, Haemophilus influenzae type b (HIB), Hepatitis B (HEP), Measles, mumps, rubella (MMR), Pneumococcal, Meningococcal, Varicella, and full vaccination. There were 358 SA3 regions covering Australia in 2016 that closely align with Local Government Areas. SA3 generally have a population of between 30,000 and 130,000 people and are often areas with geographic and socioeconomic similarities [22]. Non-mapped SA3s without identification codes are not included in the main study but used for robustness checks.

Data on baseline regional characteristics at the SA3 level were sourced from the Census of Population and Housing in 2016 available in the ABS. It provides information on regional sociodemographic factors that are potentially associated with immunisation coverage and policy enforcement. The regional data from the ABS were matched with the coverage data from the AIR using SA3 identification.

2.2. Specification

With observations available pre- and post- intervention in a longitudinal dataset, NSW that introduced the policy in January 2018 and WA that introduced the policy in July 2019, along with observations not under NJNP as counterfactuals, were used for main estimation under a quasi-experimental design. For VIC and QLD, where No Jab No Pay and NJNP were introduced simultaneously in January 2016, it is difficult to empirically separate out

Fig. 1. Implementation of No Jab No Play across states in Australia. Notes: NJNP mandates require that children must be up to date with the childhood vaccine schedule, on a recognised catch-up program, or medically exempt to enrol in childhood services. NJNP policies differed across states in terms of the form of childcare services to which the requirements applied. NSW attached mandates to enrolment in childcare services, WA attached mandates to long day care, family day care, pre-kindergarten and kindergarten. Victoria applied mandates to long day care, family day care and occasional care. Queensland's policy applied mandates to childcare services, however enforcement of this mandate is dependent on the discretion of the childcare provider. Source: National Centre for Immunisation Research and Surveillance (2021).

the impact of NJNP from that of No Jab No Pay, and thus the analysis for these states using a repeated measures group difference modelling approach is provided in Appendix B.

To make use of the differential timings of policy introduction in NSW and WA, the effect of NJNP is modelled as follows:

$$Coverage_{ijt} = f\,(postNJNP\,year1_{ijt} + postNJNP\,year2_{ijt} + State_j + Year_t + T_t + {T_t}^2 + X_{ij})$$

where i indexes SA3s, j indexes state or territory, and t indexes quarter-year. $Coverage_{ijt}$ is the vaccine coverage rates at 1, 2, 5 years of age, $post\,NJNP\,year\,1_{ijt}$ and $post\,NJNP\,year\,2_{ijt}$ equal to 1 if the observation is in the first and second year post NJNP respectively and 0 otherwise, $Year_t$ is year indicators, T_t and ${T_t}^2$ are linear and quadratic time trends, $state_j$ equal to 1 for NSW and WA and 0 for SA, TAS, ACT, and NT, and X_{ij} is a set of baseline confounding regional characteristics that potentially impact policy introduction and immunisation coverage.

The regional covariates include demographic factors (median age of usual residents, total fertility rates, average number of all children in a family, population density, proportion married, proportion renting, proportion aboriginal and torres strait islander [ATSI] peoples, and proportion speaking non-English at home); and socioeconomic factors (median total income, the Index of Relative Socio-economic Advantage and Disadvantage [IRSAD], unemployment rate, Gini coefficient, numbers of single and partnered parenting payments cases, numbers of Family Tax Benefit [FTB] A cases, numbers of taxpayers with private health insurance, proportion with bachelor degree, advanced diploma or diploma, certificate, and year 12 or equivalent).

2.3. Standard regression for mean policy effects

To examine the average relationship between policy intervention and coverage, generalised linear models with a binomial distribution and a logit link function are employed for coverage ranged 0–1. Standard errors were adjusted for unspecified heteroscedasticity and within-SA3 correlation over time. Estimates are expressed as percentage points (average marginal effects multiplied by 100%). Regressions with and without adjustment of time and regional factors were performed to gauge the consequence of temporal trends and regional heterogeneity. Exploratory subgroup analysis was conducted across area socioeconomic status.

2.4. Quantile regression for differential policy effects across quantiles

To test whether the impact of the policy varies across the distribution of coverage, a quantile regression approach is adopted adjusting for within-SA3 correlation [13]. This specification relaxes the assumption in standard regressions that the policy effect is homogeneous across the distribution of coverage. Instead of modelling the mean change in coverage associated with the policy, quantile regressions estimate the change in coverage at different points of the distribution, and provide a more complete picture of the policy impact [14]. Quantile regressions also have advantages of being more robust to non-normal errors and outliers [15].

2.5. Robustness checks

Several sensitivity analyses were also conducted (see Appendix Table A1). First, an enlarged sample including additional non-mapped SA3s was used along with mapped SA3s between January 2016 and December 2019. By virtue of identification codes unavailable for non-mapped SA3s to link with the ABS data, no covariates were included for this estimation. Second, the enlarged sample including non-mapped and mapped SA3s was further extended to June 2020 to include the period when the Coronavirus pandemic started to occur. Third, an interrupted times series (ITS) specification that included the level change (a post-policy indicator) and slope change (a post-policy indicator $\times$ T_t) was modelled. Fourth, a difference in difference (DID) approach was adopted separately for NSW and WA between January 2016 and June 2020: NSW dummy, post-January 2018 and their interaction were included in the model for NSW; and WA dummy, post-July 2019 and their interaction were included in the model for WA.

3. Results

3.1. Sample characteristics

Table 1 reports (1) the mean vaccine coverage rates of all states and territories in 2016, (2) the mean vaccine coverage rates for observations that had NJNP, (3) the mean vaccine coverage rates for observations that had not been under NJNP, and (4) baseline regional characteristics at the SA3 level in 2016. The vaccination rates at baseline were high, at 93.4% for one-year-olds, 91.2% for two-year-olds and 93.2% for five-year-olds. Comparing observations with and without NJNP, the mean coverage was consistently higher across vaccines for observations affected by NJNP. Appendix Fig. A1 shows trends in coverage rates for intervention and control states. The coverage at the SA3 level at baseline ranged from 73.6% to 100%, with particularly low coverage located in northeast NSW, southeast Queensland, southeast Perth, and south Canberra (see Appendix Fig. A2 for heatmaps).

3.2. Average policy effects using standard regression

Table 2(a) reports the policy effects on coverage following the policy across vaccines at one year of age. Significant but small increases in coverage following the introduction of NJNP were observed in models including state indicator (top panel), state and time indicators (middle panel), and state and time indicators and regional characteristics (bottom panel), with the estimates being smaller and less significant after controlling for regional differences. In the covariate adjusted model, there were significant increases of 0.68% (95 %CI 0.22; 1.24) in DTP, 0.67% (95 %CI 0.20; 1.14) in Polio, 0.65% (95 %CI 0.17; 1.14) in HIB, 0.73% (95 %CI 0.25; 1.21) in HEP and 0.56% (95 %CI 0.05; 1.07) in full immunisation in the second year following less significant increases in the first year.

Table 2(b) reports the policy effects on coverage following the policy across vaccines at two years of age. Compared to the coverage without NJNP, the increases in coverage were significant post-NJNP year 1 for DTP (0.58%, 95 %CI: 0.18; 0.98), Polio (0.35%, 95 %CI: 0.07; 0.63), HEP (0.37%, 95 %CI: 0.08; 0.65), MMR (0.72%, 95 %CI: 0.32; 1.12), MenC (0.35%, 95 %CI: 0.03; 0.66), Varicella (0.60%, 95 %CI: 0.17; 1.02), and full immunisation (0.49, 95 %CI: 0.00; 0.97); and post-NJNP year 2 for DTP (0.76%, 95 %CI: 0.29; 1.24), Polio (0.49%, 95 %CI: 0.14; 0.84), HIB (0.63%, 95 %CI: 0.24; 1.02), HEP (0.55%, 95 %CI: 0.20; 0.90), MMR (0.80%, 95 %CI: 0.30; 1.31), MenC (0.45%, 95 %CI: 0.05; 0.84), Varicella (0.77%, 95 %CI: 0.23; 1.31), and full immunisation (1.15%, 95 %CI: 0.53; 1.77).

Table 2(c) reports the policy effects on coverage following the policy across vaccines at five years of age. Similar to the results for ages two and five, the increase in coverage post policy was significant but small, with an increase of 0.38% (95 %CI 0.09; 0.67) for DTP, 0.41% (95 %CI 0.14; 0.69) for Polio, and 0.38% (95 %CI 0.08; 0.67) for full immunisation in the first year; and an increase of 0.72% (95 %CI 0.27; 1.18) for DTP, 0.74% (95 %CI 0.30; 1.17) for

Table 1
National coverage and regional characteristics (SA3), Jan 2016-Dec 2019.

	Full sample in 2016 (mean)	Subsample without NJNP (mean)	Subsample with NJNP (mean)
Coverage for 1-year-olds			
DTP	94.2%	94.4%	94.8%
Polio	94.2%	94.4%	94.8%
HIB	93.9%	94.2%	94.6%
HEP	94.1%	94.4%	94.8%
Pneumo	93.9%	94.6%	95.3%
Fully	93.4%	93.8%	94.0%
Coverage for 2-year-olds			
DTP†	96.2%	93.7%	93.1%
Polio	96.1%	96.2%	96.4%
HIB	95.2%	95.2%	95.0%
HEP	96.0%	96.1%	96.3%
MMR‡	92.8%	93.0%	93.4%
MenC	95.0%	95.3%	95.4%
Varicella	92.7%	92.7%	93.1%
Fully	91.2%	90.6%	91.1%
Coverage for 5-year-olds			
DTP	93.8%	94.1%	94.8%
Polio	93.9%	94.1%	94.9%
Fully	93.2%	93.7%	94.7%
Regional characteristics at baseline: Demographic factors			
Median age	38.98		
Total fertility per female	1.88		
Average no. all children	1.85		
Log population density*	5.36		
Married %	48.46		
Rented %	30.56		
Aboriginal and Torre Strait Islanders %	4.34		
Total born overseas %	23.11		
Speak non-English at home %	17.38		
Regional characteristics at baseline: Socioeconomic factors			
Log median total income⁑	10.86		
IRSAD lowest quintile	0.19		
IRSAD Q2	0.22		
IRSAD Q3	0.18		
IRSAD Q4	0.18		
IRSAD highest quintile	0.23		
Unemployment rate	6.72		
Total income Gini coefficient	0.46		
Log no. parenting payments-single cases	6.39		
Log no. parenting payments-partnered cases	5.24		
Log no. Family Tax Benefit A cases	8.19		
Bachelor degree %	14.28		
Advanced diploma/diploma %	8.49		
Certificate %	19.62		
Completed year12 or equivalent %	48.48		
Log taxpayers with private insurance	9.96		

Notes: Based on the National Immunisation Program Schedule, DTP, Polio, HIB, HEP, Pneumococcal and fully immunised are assessed at one year of age. DTP, Polio, HIB, HEP, MMR, Meningococcal, Varicella and fully immunised (DTP dose 4 included in March 2017) are assessed at two years of age. DTP, Polio, MMR and fully immunised (MMR removed in December 2017) are assessed at five years of age.† In March 2017, dose 4 DTP for children aged 2 years was included in the definition of fully immunised, causing a drop in the coverage rate. ‡ In December 2017, dose 2 MMR for children aged 60–63 months was removed. * The log of population density is constructed as the log of population density plus one to adjust for less-than-one values. ⁑ Median income is inflated to 2020 dollars using the Consumer Price Index from the ABS. IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

Polio, and 0.71% (95 %CI 0.25; 1.16) for full immunisation in the second year.

3.3. Distributional policy effects across quantiles

Fig. 2 shows the effects of the NJNP policy by quantile of baseline immunization coverage. NJNP had larger effects on coverage at 1 year of age when baseline immunisation coverage was in the 45th–85th percentiles, whilst the policy effects were significant at two and five years of age across almost the entire coverage distribution expect the very top and bottom tails. Importantly, despite having positive signs at the lowest tails, the policy effect estimates had a large dispersion and were insignificant for the age of one, two and five.

3.4. Policy effect variation by socioeconomic status

The variation in policy response by baseline IRSAD is presented in Fig. 3 to assess if the policy had unequal impact across SA3s with different socioeconomic status. The policy effects were largest for areas with IRSAD at the fourth quintile across age groups. Significant policy effects were also observed for areas with IRSAD at the second quintile at age two and the lowest quintile at age five. The improvement in coverage was least pronounced in areas with highest socioeconomic status.

3.5. Robustness analysis

Robustness checks show consistent findings including non-mapped SA3s, extending to the Coronavirus period, using an ITS

Table 2
Average policy effects on coverage at 1, 2 and 5 year of age.

(a) 1-year-olds	DTP	Polio	HIB	HEP	Pneumo	Fully		
Post-policy year1	0.302**	0.291**	0.375***	0.285**	0.492***	0.180		
	(0.125)	(0.127)	(0.127)	(0.127)	(0.121)	(0.132)		
Post-policy year2	0.835***	0.836***	0.914***	0.882***	1.806***	0.845***		
	(0.172)	(0.173)	(0.175)	(0.174)	(0.148)	(0.181)		
State indicator	√	√	√	√	√	√		
Post-policy year1	0.445**	0.424**	0.419**	0.401**	−0.418**	0.184		
	(0.192)	(0.197)	(0.198)	(0.199)	(0.204)	(0.207)		
Post-policy year2	0.901***	0.896***	0.849***	0.910***	0.133	0.702**		
	(0.292)	(0.294)	(0.304)	(0.299)	(0.345)	(0.313)		
State indicator	√	√	√	√	√	√		
Time indicator/trend	√	√	√	√	√	√		
Post-policy year1	0.349*	0.326*	0.336*	0.322*	−0.434**	0.145		
	(0.179)	(0.183)	(0.187)	(0.183)	(0.182)	(0.193)		
Post-policy year2	0.682***	0.671***	0.653***	0.728***	0.010	0.560**		
	(0.236)	(0.238)	(0.247)	(0.246)	(0.291)	(0.261)		
State indicator	√	√	√	√	√	√		
Time indicator/trend	√	√	√	√	√	√		
Regional covariates	√	√	√	√	√	√		
(b) 2-year-olds	DTP	Polio	HIB	HEP	MMR	MenC	Varicella	Fully
Post-policy year1	−0.775***	0.235**	0.035	0.286***	0.582***	0.314***	0.308**	0.288*
	(0.159)	(0.109)	(0.126)	(0.111)	(0.136)	(0.119)	(0.150)	(0.158)
Post-policy year2	−0.408*	0.155	−0.211	0.263	0.826***	0.385**	1.370***	1.320***
	(0.222)	(0.165)	(0.180)	(0.164)	(0.190)	(0.172)	(0.184)	(0.216)
State indicator	√	√	√	√	√	√	√	√
Post-policy year1	0.722***	0.211	0.141	0.234	0.859***	0.307	0.727***	0.590**
	(0.233)	(0.184)	(0.207)	(0.187)	(0.232)	(0.206)	(0.229)	(0.263)
Post-policy year2	1.031***	0.271	0.503*	0.331	1.075***	0.389	1.020***	1.391***
	(0.324)	(0.285)	(0.284)	(0.289)	(0.342)	(0.305)	(0.350)	(0.380)
State indicator	√	√	√	√	√	√	√	√
Time indicator/trend	√	√	√	√	√	√	√	√
Post-policy year1	0.580***	0.350**	0.216	0.367**	0.720***	0.348**	0.599***	0.487**
	(0.206)	(0.142)	(0.168)	(0.144)	(0.205)	(0.160)	(0.217)	(0.247)
Post-policy year2	0.764***	0.493***	0.629***	0.549***	0.805***	0.445**	0.771***	1.147***
	(0.244)	(0.177)	(0.200)	(0.180)	(0.260)	(0.202)	(0.276)	(0.316)
State indicator	√	√	√	√	√	√	√	√
Time indicator/trend	√	√	√	√	√	√	√	√
Regional covariates	√	√	√	√	√	√	√	√
(c) 5-year-olds	DTP	Polio	Fully					
Post-policy year1	0.735***	0.807***	1.101***					
	(0.131)	(0.130)	(0.132)					
Post-policy year2	1.209***	1.310***	1.519***					
	(0.200)	(0.193)	(0.200)					
State indicator	√	√	√					
Post-policy year1	0.686***	0.712***	0.673***					
	(0.221)	(0.215)	(0.230)					
Post-policy year2	1.251***	1.237***	1.225***					
	(0.341)	(0.331)	(0.353)					
State indicator	√	√	√					
Time indicator/trend	√	√	√					
Post-policy year1	0.380***	0.413***	0.378**					
	(0.147)	(0.142)	(0.151)					
Post-policy year2	0.725***	0.736***	0.706***					
	(0.231)	(0.221)	(0.230)					
State indicator	√	√	√					
Time indicator/trend	√	√	√					
Regional covariates	√	√	√					

Note: The sample includes NSW, WA and control states. Significant at ***1%, **5% and *10%.

specification, and using a DID approach. A slight decrease in coverage in 2020 might reflect the interruption of the pandemic on recording and vaccination activities, or the consequences of childcare service shutdown (see Appendix Table A1). The estimates from the ITS specification show that there was an increase in the level of coverage following NJNP, although the increasing trend was lower post NINP compared to post No Jab No Pay. The estimates from the DID approach show more significant increases in NSW.

4. Discussion

This study examined the changes in immunisation coverage associated with the introduction of the NJNP policies in NSW and WA that conditioned childcare service entry on vaccine status without allowing for conscientious objection exemptions. The differential timing of policy rollout and the availability of intervention-and-control and before-and-after study design add confidence in identifying the policy effects. The results show that

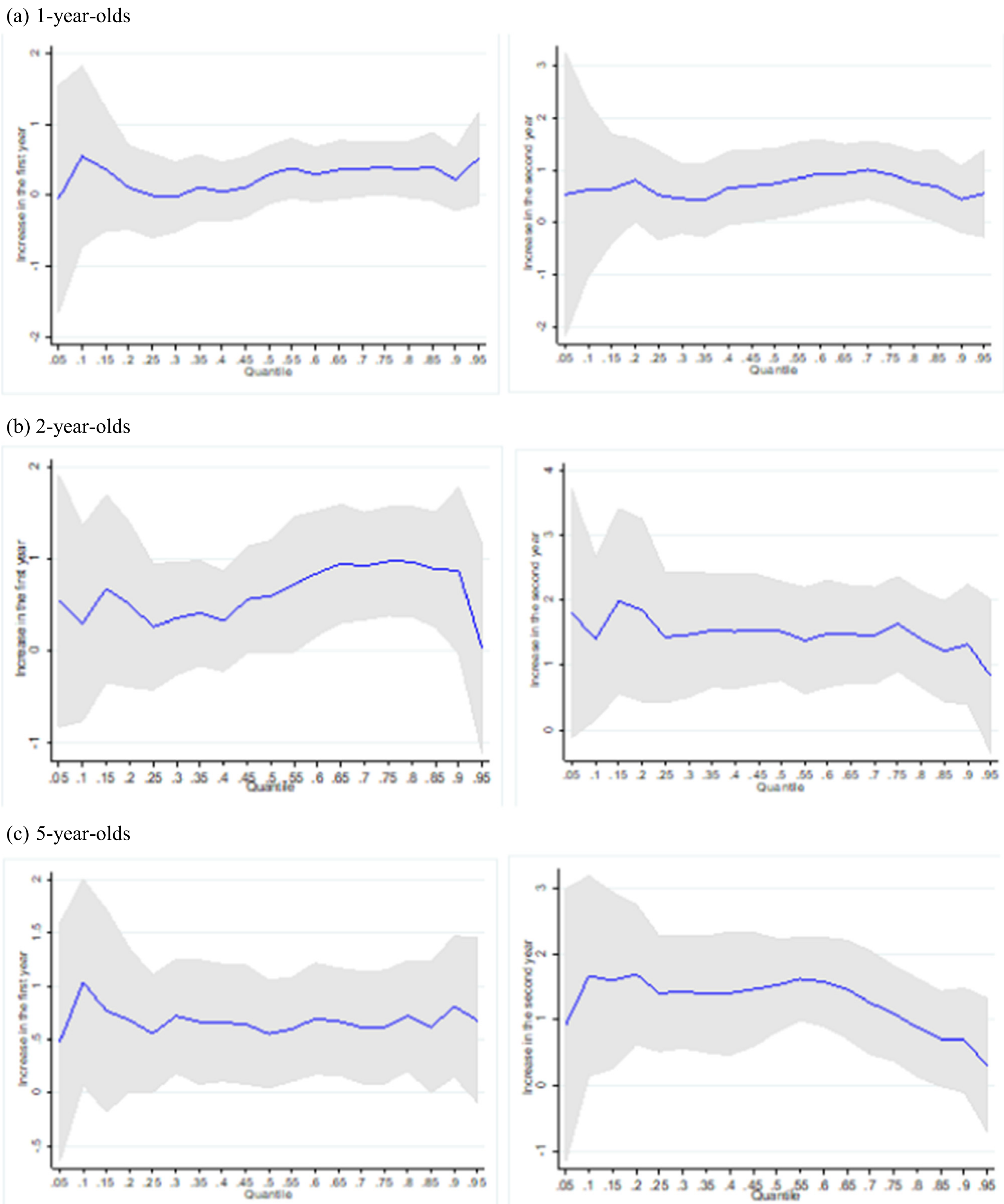

Fig. 2. Distributional policy effects across coverage quantiles. Notes: Quantile regressions control for state indicator and time indicator and trends, with cluster-adjusted standard errors.

immunisation requirements for childcare centres without conscientious objection exemptions led to significant but small increases in the level of coverage rates by, on average, 1) a 0.1% (insignificant) increase in the first year and 0.6% increase in the second year at one year of age, 2) a 0.5% increase in the first year and 1% increase in the second at two years of age, and 3) a 0.4% increase in the first year and 0.7% in the second year at five years of age, controlling for aggregate time trends as well as temporal and locational variations. The rates at which children are typically enrolled in childcare in Australia might partially explain the lower estimates for one-year-olds. Prior to their first year only 12.4% of children are enrolled in formal care which increases to 41.9% for one-

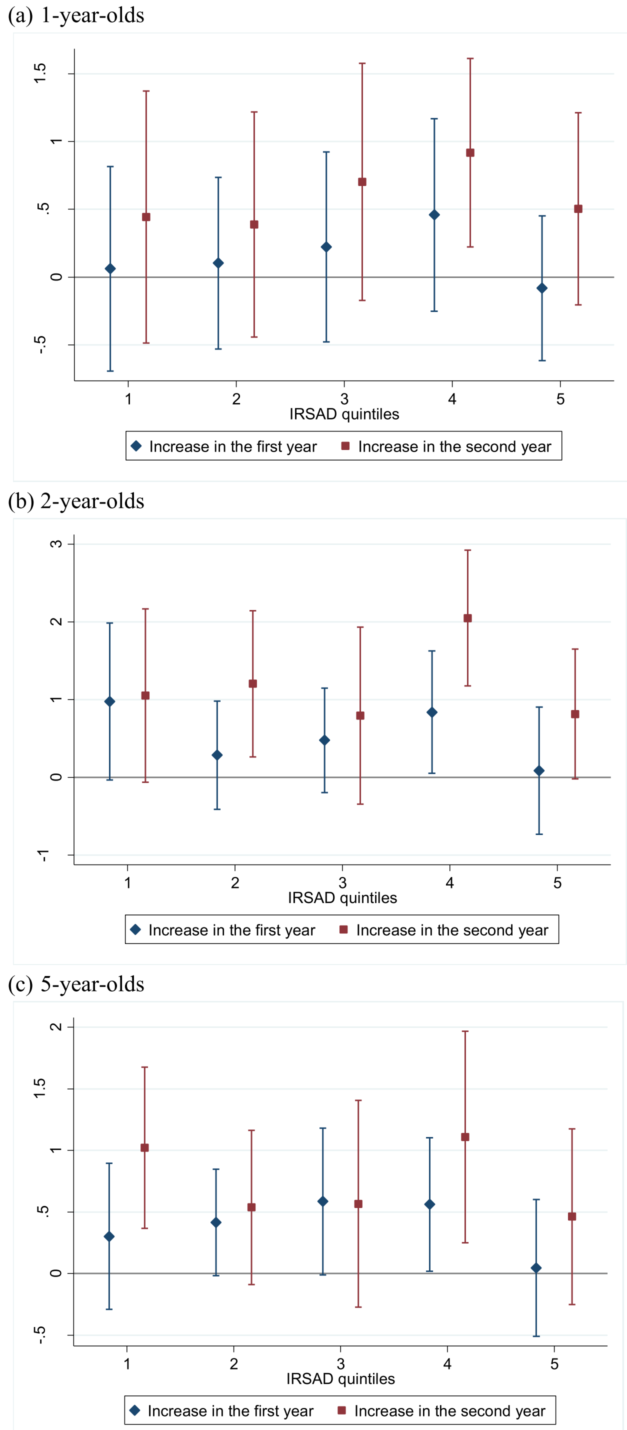

Fig. 3. Policy effect variation by socioeconomic status (IRSAD) quintiles. Notes: Regressions including the interaction between policy indicators and IRSAD quintile indicators were conducted with cluster-adjusted standard errors. IRSAD is a socioeconomic advantage and disadvantage index that summarises income, education, occupation, and dwelling conditions of households within an area.

year-olds, 58.3% for two-year-olds and declines to 28% by five-years old [23]. Parents whose children have not yet reached the age to enrol in childcare services may not be nudged by the policy.

The study also reveals the differential policy effect across the distribution of coverage. While the policy effect was significant at the middle quantiles, there was a wide dispersion at the lowest quantiles which resulted in insignificant policy effect estimates. The large variation in policy effects at the lowest tail of the distribution potentially reflects the heterogeneity within the under-vaccinated group between parents who intentionally refuse and those who face practical barriers [16]. The lack of significant increases at the lowest tail of the distribution, in contrast to significant policy responses at the middle distribution, may also imply the persistency in low immunisation coverage perhaps due to vaccine hesitancy and refusal or a failure to address practical barriers in some areas. Australia and other countries have observed consistent geographic clustering of nonmedical exemptions [17,18]. While Australia vaccine policies has been largely successful in achieving high childhood vaccination rates for community immunity, geographical clustering of unvaccinated children increases risks of local outbreaks [17].

Another important finding revealed in the exploratory subgroup analysis is the smallest policy effects for SA3s in the highest socioeconomic quintiles and some insignificant policy effects for SA3s in the lowest socioeconomic quintiles. This is of particular concern given childhood immunisation coverage was lowest at either end of the socioeconomic spectrum [1,19]. Previous studies have demonstrated that higher median household income and socioeconomic advantage is significantly associated with higher percentages of personal belief exemptions and registered conscientious objectors [18,20]. Vaccine mandates at the federal level link vaccine status to means-tested financial incentives that higher income families are not eligible to receive, NJNP was assumed to address this gap, however these results suggest that higher socio-economic status parents who are vaccine hesitant or refusing are still able to evade uptake. Qualitative research on vaccine rejecting parents found that some parents opt to organise informal care arrangements rather than be nudged by NJNP policies [21].

While statistically significant, the improvement in coverage following the introduction of vaccine requirements for childcare enrolment without conscientious objection exemptions was small and heterogenous. The policy effect was insignificant and smallest in more socioeconomically advantaged areas where coverage also tended to be lower; and was also insignificant and largely dispersed in areas with low coverage. More targeted approaches may need to be considered as parents with lower socio-economic status may require assistance with practical barriers, and policies that employ behavioural conditionality may exacerbate disadvantage if barries are not addressed [8,21]. Migrant and refugee parents who often face more practical barriers to submitting documentation need to be provided with adequate assistance [24]. Efforts should be made to ensure that behavioural conditionality does not contribute to unequitable access to childcare.

There are some limitations to this study. The study covered a relatively short period post-NJNP for WA which means the policy effect may be currently underestimated; however, numerous analyses of vaccine mandates show a tapering of improvement post-intervention [1,5]. Due to lack of individual-level data, vaccine attitudes or practical barriers cannot be directly assessed. While the study design employed counterfactual controls, the policy effects of NJNP cannot disentangled from other possible state-level programs. Further, the study investigated the policy impact on immunisation coverage and this metric should not be the sole means to evaluate policies that employ behavioural conditionality.

Despite small improvement in coverage rates, the study implies that vaccine mandates might play a role in mainlining high coverage in Australia. Further research that incorporates longer study periods and accounts for the effect of a recent surge in vaccine hesitancy would allow the test of the extent to which vaccine mandates help maintain high coverage over time. Future studies should also consider individual level data to assess the intention behind parental vaccine decisions and the barriers that remain to better understand the causes of unresponsiveness to the policy initiatives aimed at increasing immunisation coverage. Comparative analysis of mandate policies and those that place administrative hurdles or other disincentives is needed to ensure a successful balance between effectiveness and equity.

5. Conclusion

With a high childhood immunisation coverage in 2016 within three to four percentage points of the aspirational target of 95%, the improvement in coverage associated with NJNP was significant but small, at 0.6% for one-year-olds, 1.0% for two-year-olds, and 0.7% for five-year-olds. NJNP was thought to address gaps in the segments of the population targeted by No Jab No Pay, yet response to the policy was dispersed and insignificant for areas with the lowest baseline coverage, and socioeconomically advantaged areas were less responsive to the intervention. Concerns around the impact of the policy on equitable access to childcare and the failure to address under-vaccination amongst higher socioeconomic status areas remain.

Research ethics approval

This study does not involve human participants.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

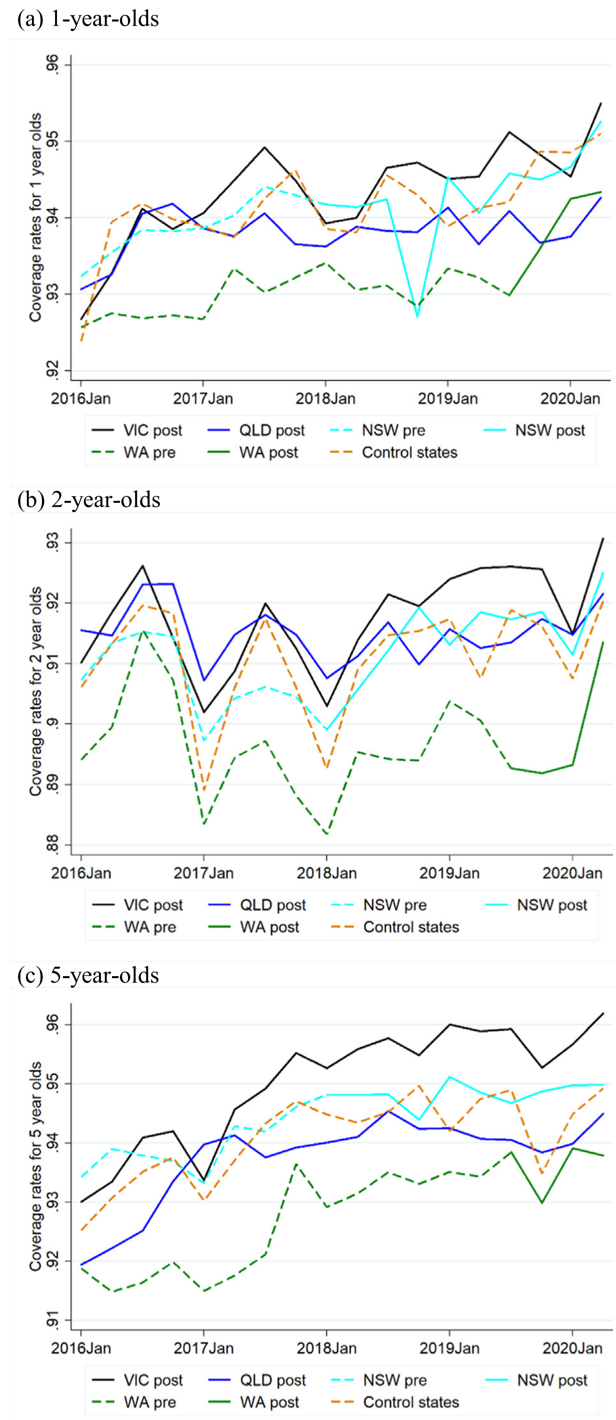

Fig. A1. Average coverage for 1-, 2- and 5-year-olds at the state level, Jan 2016-Jun 2020. Notes: Solid and dash lines indicate periods with and without NJNP in place, respectively.

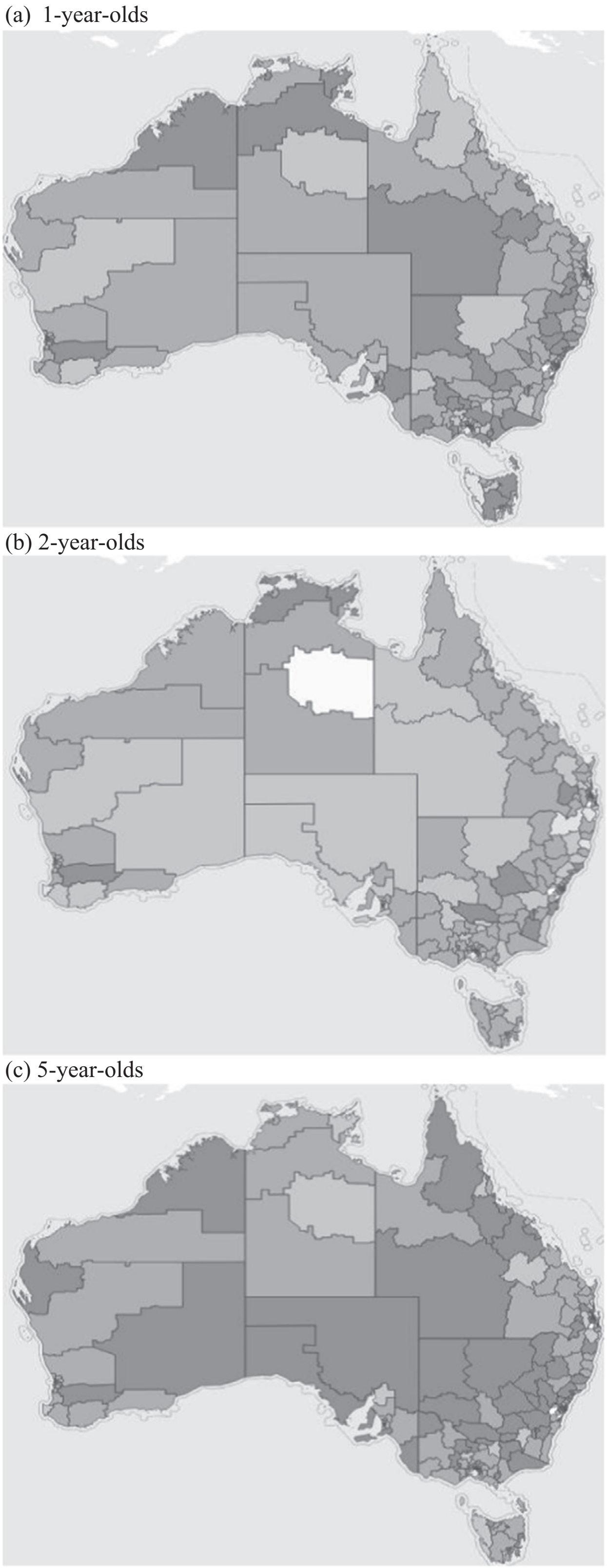

Fig. A2. Fully vaccination rates at the SA3 level in 2016. Notes: Gradients of colour from the lightest to the darkest represent coverage ≤80, 80–85, 85–90, 90–95, and ≥95 respectively. Source: Australian Immunisation Register on Australian Urban Research Infrastructure Network.

Table A1
Sensitivity analyses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Inc non-mapped SA3s			Extending to Jun 2020			ITS specification		
	Age 1	Age 2	Age 5	Age 1	Age 2	Age 5	Age 1	Age 2	Age 5
Post-policy year1	0.219	0.537**	0.691***	0.143	0.387	0.526***			
	(0.208)	(0.267)	(0.229)	(0.181)	(0.265)	(0.194)			
Post-policy year2	0.862**	1.409***	1.308***	0.839**	1.385***	1.283***			
	(0.339)	(0.373)	(0.348)	(0.332)	(0.372)	(0.344)			
Post-policy year3				0.630*	1.457***	1.127***			
				(0.358)	(0.461)	(0.391)			
Post-policy							2.021***	2.215**	1.564**
							(0.753)	(0.916)	(0.662)
Post-policy × T							−0.140**	−0.120*	−0.085*
							(0.057)	(0.070)	(0.050)
State indicator	√	√	√	√	√	√	√	√	√
Time indicator/trend	√	√	√	√	√	√	√	√	√
Regional covariates	√	√	√	√	√	√	√	√	√

	(10)	(11)	(12)	(13)	(14)	(15)
	DID specification					
	NSW			WA		
	Age 1	Age 2	Age 5	Age 1	Age 2	Age 5
NSW	1.215***	1.002**	0.883**			
	(0.424)	(0.493)	(0.368)			
NSW × post Jan 2018	−0.218	0.287	0.002			
	(0.195)	(0.298)	(0.157)			
WA x				−0.266	−0.145	−0.583
				(0.434)	(0.559)	(0.473)
WA × post Jul 2019				−0.206	−0.492	0.513*
				(0.291)	(0.395)	(0.275)
State indicator	√	√	√	√	√	√
Time indicator/trend	√	√	√	√	√	√
Regional covariates	√	√	√	√	√	√

Notes: The sample includes NSW, WA and control states. All models controlled for state and time indicators, time trends and regional covariates, with cluster-adjusted standard errors.

Appendix B

Table B1
Difference in coverage between VIC and QLD, and control states.

(a) One-year-olds	DTP	Polio	HIB	HEP	Pneumo	Fully		
Different in 2016	0.888***	0.899***	0.951***	1.022***	1.049***	0.982***		
	(0.295)	(0.296)	(0.300)	(0.295)	(0.325)	(0.325)		
Different in 2017	0.870***	0.893***	0.923***	0.745**	1.005***	0.962***		
	(0.304)	(0.310)	(0.315)	(0.299)	(0.315)	(0.321)		
Different in 2018	0.809***	0.807***	0.849***	0.737**	0.689**	0.857***		
	(0.304)	(0.305)	(0.298)	(0.301)	(0.275)	(0.304)		
Different in 2019	0.419	0.453	0.457	0.549*	0.339	0.618**		
	(0.304)	(0.306)	(0.310)	(0.313)	(0.257)	(0.310)		
(b) Two-year-olds	DTP	Polio	HIB	HEP	MMR	MenC	Varicella	Fully
Different in 2016	0.440*	0.759***	0.944***	0.756***	0.826**	1.002***	0.894**	1.207***
	(0.227)	(0.222)	(0.248)	(0.241)	(0.357)	(0.263)	(0.353)	(0.384)
Different in 2017	1.533***	0.799***	1.025***	0.842***	1.027***	0.849***	0.978***	1.591***
	(0.322)	(0.206)	(0.227)	(0.198)	(0.305)	(0.224)	(0.300)	(0.341)
Different in 2018	1.280***	0.847***	1.038***	0.868***	1.173***	0.945***	1.157***	1.408***
	(0.362)	(0.224)	(0.253)	(0.228)	(0.339)	(0.264)	(0.371)	(0.421)
Different in 2019	0.859***	0.837***	0.772***	0.810***	0.708**	0.598**	0.583*	1.018***
	(0.307)	(0.237)	(0.286)	(0.240)	(0.326)	(0.265)	(0.315)	(0.344)
(c) Five-year-olds	DTP	Polio	MMR	Fully				
Different in 2016	0.873***	0.894***	0.566	0.910**				
	(0.319)	(0.317)	(0.369)	(0.370)				
Different in 2017	1.237***	1.272***	0.931***	1.238***				
	(0.307)	(0.311)	(0.280)	(0.329)				
Different in 2018	1.126***	1.133***		1.063***				
	(0.269)	(0.265)		(0.279)				
Different in 2019	1.062***	1.000***		1.032***				
	(0.261)	(0.258)		(0.263)				

(continued on next page)

Table B1 (*continued*)

(a) One-year-olds	DTP	Polio	HIB	HEP	Pneumo	Fully		
State indicator	√	√	√	√	√	√	√	√
Time indicator/trend	√	√	√	√	√	√	√	√
Regional covariates	√	√	√	√	√	√	√	√

Notes: VIC and QLD introduced the NJNP and No Jab No Pay in 2016 and were under both policies during the entire study period. The policy indicator (N/NPij) equals to 1 for VIC and QLD and 0 for control states. The difference in coverage between the treated and untreated in each year was modelled as follows: $Coverage_{ijt} = f(NJNP_{ij} + NJNP_{ij} x\ Year_t + Year_t + State_j + T_t + T_t^2 + X_{ij})$ The results are reported in Table B1, which shows significant difference between states with the NJNP and No Jab No Pay and states with No Jab No Pay only across age groups over years, in the order of around 1%. The sample includes VIC, QLD and control states. All models adjust for clustering of standard errors.

References

[1] Li A, Toll M. Removing conscientious objection: the impact of ‘No Jab No Pay’ and ‘No Jab No Play’ vaccine policies in Australia. Prev Med 2021;145():106406. https://doi.org/10.1016/j.ypmed.2020.106406.

[2] Gravagna K, Becker A, Valeris-Chacin R, Mohammed I, Tambe S, Awan FA, et al. Global assessment of national mandatory vaccination policies and consequences of non-compliance. Vaccine 2020;38(49):7865–73. https://doi.org/10.1016/j.vaccine.2020.09.063.

[3] Omer SB, Betsch C, Leask J. Mandate vaccination with care. Nature 2019;571(7766):469–72. https://doi.org/10.1038/d41586-019-02232-0.

[4] Rezza G. Mandatory vaccination for infants and children: the Italian experience. Pathogens Global Health 2019;113(7):291–6. https://doi.org/10.1080/20477724.2019.1705021.

[5] Delamater PL, Pingali SC, Buttenheim AM, Salmon DA, Klein NP, Omer SB. Elimination of nonmedical immunization exemptions in California and school-entry vaccine status. Pediatrics 2019;143(6). https://doi.org/10.1542/peds.2018-3301.

[6] Trent M, Zhang E, Chughtai A, MacIntyre C. Parental opinions towards the “No Jab, No Pay” policy in Australia. Vaccine 2019;37(36):5250–6. https://doi.org/10.1016/j.vaccine.2019.07.066.

[7] Rezza G, Ricciardi W. No jab, no pay and vaccine mandates: Do compulsory policies increase vaccination coverage? The Italian experience. Vaccine 2020;38(33):5089–189. https://doi.org/10.1016/j.vaccine.2020.05.043.

[8] MacDonald NE, Harmon S, Dube E, et al. Mandatory infant & childhood immunization: Rationales, issues and knowledge gaps. Vaccine 2018;36(39):5811–8. https://doi.org/10.1016/j.vaccine.2018.08.042.

[9] Hull BP, Beard FH, Hendry AJ, Dey A, Macartney K. “No jab, no pay”: catch-up vaccination activity during its first two years. Med J Aust 2020;213(8):364–9. https://doi.org/10.5694/mja2.50780.

[10] Attwell K, Seth R, Beard F, Hendry A, Lawrence D. Financial interventions to increase vaccine coverage. Pediatrics 2020;146(6). https://doi.org/10.1542/peds.2020-0724.

[11] Armiento R, Hoq M, Kua E, Crawford N, Perrett KP, Elia S, et al. Impact of Australian mandatory ‘No Jab, No Pay’and ‘No Jab, No Play’immunisation policies on immunisation services, parental attitudes to vaccination and vaccine uptake, in a tertiary paediatric hospital, the Royal Children’s Hospital, Melbourne. Vaccine 2020;38(33):5231–40. https://doi.org/10.1016/j.vaccine.2020.05.094.

[12] Vaz OM, Ellingson MK, Weiss P, Jenness SM, Bardají A, Bednarczyk RA, et al. Mandatory vaccination in Europe. Pediatrics 2020;145(2). https://doi.org/10.1542/peds.2019-0620.

[13] Machado JA, Parente P, Santos Silva J. QREG2: Stata module to perform quantile regression with robust and clustered standard errors; 2021.

[14] Cameron AC, Trivedi PK. Microeconometrics using stata: Stata press College Station, TX; 2010.

[15] Baum CF. Quantile regression; 2013.

[16] Toll M, Li A. Vaccine sentiments and under-vaccination: Attitudes and behaviour around Measles, Mumps, and Rubella vaccine (MMR) in an Australian cohort. Vaccine 2021;39(4):751–9. https://doi.org/10.1016/j.vaccine.2020.11.021.

[17] Omer SB, Enger KS, Moulton LH, Halsey NA, Stokley S, Salmon DA. Geographic clustering of nonmedical exemptions to school immunization requirements and associations with geographic clustering of pertussis. Am J Epidemiol 2008;168(12):1389–96. https://doi.org/10.1093/aje/kwn263.

[18] Beard FH, Hull BP, Leask J, Dey A, McIntyre PB. Trends and patterns in vaccination objection, Australia, 2002–2013. Med J Aust 2016;204(7):275. https://doi.org/10.5694/mja15.01226.

[19] Fielding JE, Bolam B, Danchin MH. Immunisation coverage and socioeconomic status–questioning inequity in the ‘No Jab, No Pay’policy. Aust N Z J Public Health 2017;41(5):455–7. https://doi.org/10.1111/1753-6405.12676.

[20] Yang YT, Delamater PL, Leslie TF, Mello MM. Sociodemographic predictors of vaccination exemptions on the basis of personal belief in California. Am J Public Health 2016;106(1):172–7. https://doi.org/10.2105/AJPH.2015.302926.

[21] Helps C, Leask J, Barclay L. “It just forces hardship”: impacts of government financial penalties on non-vaccinating parents. J Public Health Policy 2018;39(2):156–69. https://doi.org/10.1057/s41271-017-0116-6.

[22] ABS. Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas cat. no. 1270.0.55.001. Australian Bureau of Statistics; 2016.

[23] AIHW. Childcare and early childhood education. Australian Institute of Health and Welfare; 2021.

[24] Paxton GA, Tyrrell L, Oldfield SB, Kiang K, Danchin MH. No Jab, No Pay—no planning for migrant children. Med J Aust 2016;205(7):296–8. https://doi.org/10.5694/mja16.00351.