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Birth order and infant health: evidence from maternal immunisation in New Zealand

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Abstract

Immunisation during pregnancy is a vital strategy to protect infants from infectious diseases in their first months of life. Drawing on administrative data from New Zealand, I analyse the relationship between birth order, maternal vaccination against pertussis and influenza, and subsequent infant hospitalisations caused by these diseases. The findings show that later-born children experience higher hospitalisation rates, likely because of increased exposure to infectious diseases through older siblings. At the same time, maternal vaccination rates decline with each pregnancy, leaving those who would benefit most from maternal immunisation the least likely to receive it.

Keywords: Keywords: birth order; maternal immunisation; child health; pertussis; influenza
JEL Classification: I10; I12; I18; C23

*Thomas Schober, Auckland University of Technology, 42 Wakefield Street, Auckland 1142; thomas.schober@aut.ac.nz. 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/. Following IDI confidentiality rules, all counts are subject to random rounding to base three.

1 Introduction

Maternal immunisation is a key public health strategy against infectious diseases. It provides crucial protection in the first months of life, when infants' immune systems are still immature and they are too young to receive their own vaccinations. Yet maternal vaccine uptake remains limited in many high-income countries. For example, during the 2022-23 season, influenza vaccination coverage among pregnant women was 47.2 % in the United States and 35 % in England, while pertussis vaccination coverage was 55.4 % and 61.5 %, respectively (Razzaghi et al., 2023; UKHSA, 2023, 2025).

In this paper, I examine how birth order shapes maternal vaccination and subsequent infant health outcomes. A growing body of literature suggests that parental behaviour in childhood differs by birth order. Later-born children receive less parental time (Black et al., 2018; Price, 2008), are breastfed at lower rates (Black et al., 2016; Buckles and Kolka, 2014; Lehmann et al., 2018), are less likely to participate in health checks and to receive childhood immunisations (Pruckner et al., 2021). There is also evidence that such disparities emerge even before birth. Parents are less likely to utilise prenatal care in later pregnancies (Brenøe and Molitor, 2018; Buckles and Kolka, 2014; Lehmann et al., 2018), and maternal use of prenatal vitamins declines with birth order (Buckles and Kolka, 2014).

Using administrative data from New Zealand, I show that mothers are less likely to receive pertussis and influenza vaccinations in higher-order pregnancies compared to first pregnancies. This pattern has significant implications for infant health. Previous research highlights the central role of the family unit in virus transmission, suggesting that older children can introduce infections from childcare or school, thereby exposing their younger siblings to these diseases. As a result, later-born children experience higher rates of hospitalisation for respiratory conditions and receive more prescriptions for contagious diseases in early life (Björkegren and Svaleryd, 2023; Daysal et al., 2021; Pruckner et al., 2021). While the existing evidence does not distinguish between specific infectious diseases, I show that the same pattern holds for those targeted by maternal immunisation—pertussis and influenza. Later-born infants are more likely to be hospitalised for these diseases than their earlier-born siblings. Taken together, these findings suggest that later-born children face multiple disadvantages: they are more exposed to infection through older siblings, while at the same time receiving reduced protection because of lower maternal and infant vaccination rates.

This study contributes to the literature on birth-order effects and health by highlighting a novel mechanism through which family dynamics and parental behaviour influence infant health outcomes. It also contributes to the broader economics literature documenting birth order differences in long-term outcomes. First-born children tend to have a health advantage in adolescence and older age (Björkegren and Svaleryd, 2023; Brenøe and Molitor, 2018), and they also outperform their siblings in educational attainment and labour market success (e.g. Black et al., 2005; Booth and Kee, 2009; Kantarevic and Mechoulan, 2006; Lehmann et al., 2018). Differences in parental (health) investment may explain part of this relationship, as a large literature stresses the importance of the early childhood environment on long-term outcomes (Almond et al., 2018; Currie, 2009).

The remainder of the paper is organised as follows. Section 2 provides background on the

diseases, maternal immunisations, and data sources, and outlines the empirical strategy. Section 3 presents the main results on the relationship between birth order, maternal and childhood immunisation, and infant hospitalisations, followed by an analysis of potential mechanisms. Section 4 concludes.

2 Background and data

2.1 Data

I use data from the Integrated Data Infrastructure (IDI), a large research database managed by Stats NZ, New Zealand's national statistics office. The IDI contains linked administrative and survey data from government agencies and other organisations at the individual level (Stats NZ, 2022).

Information on births registered with the Department of Internal Affairs (DIA) is used to identify all children born to a woman, to determine their birth order, and to obtain birth weight. Birth order is defined based on live births only. To account for the possibility that migrant mothers may have had children overseas, I use information on the number of siblings when identifying first births. Information on vaccination uptake comes from the Aotearoa Immunisation Register, which replaced the National Immunisation Register in 2023. The register records detailed information on each vaccination event, including vaccine type and date of administration. I use these data to identify maternal receipt of influenza and pertussis vaccines during pregnancy, defined as vaccinations administered in the nine months prior to a child's birth month.

In additional analysis, I use the immunisation register to measure whether infants are fully immunised at age 12 months, as defined by the New Zealand National Immunisation Schedule. This schedule includes, among other vaccines, three doses of a combined vaccine that protects against diphtheria, tetanus, pertussis, polio, hepatitis B, and Haemophilus influenzae type b (Hib). Although the schedule underwent several changes during the observation period, it consistently included infant immunisations against pertussis (Health New Zealand, 2025b). Influenza immunisation is available for everyone over 6 months of age, but it is not part of the National Immunisation Schedule and is therefore not included in this outcome measure.

To identify children's hospitalisations for infectious diseases, I use publicly funded hospital discharge records provided by the Ministry of Health. These data contain detailed information on hospital events and associated diagnoses. Hospitalisations are classified by disease using International Classification of Diseases, 10th Revision (ICD-10) codes: pertussis (A37.1, A37.9), influenza (J09–J11), and respiratory syncytial virus (RSV; J12.1, J20.5, J21.0, and B97.4).

Additional information on health care during pregnancy comes from the National Maternity Collection, which includes records on the number of prenatal health care visits provided by the Lead Maternity Carer and the number of ultrasound scans performed.

2.2 Pertussis and influenza

Pertussis, also known as whooping cough, is a highly contagious disease of the respiratory tract. Infants are most strongly affected and have the highest risk of hospitalisation and death. Pertussis is endemic worldwide, with peaks that occur every 3-5 years. A recent review of

the burden of pertussis disease in infants shows that incidence rates in those aged <2–3 months were substantial in all countries with available data, exceeding 1000 cases per 100,000 population during outbreaks (Kandeil et al., 2020).

In New Zealand, a major epidemic between 2011 and 2014 led to the hospitalisation of hundreds of children and the deaths of three infants younger than six weeks (Howe et al., 2020). To illustrate the age distribution of severe disease, Figure 1 (left panel) shows the number of hospitalisations for pertussis by month of age in New Zealand in the years 2000-2023. The distribution of pertussis cases is highly skewed towards early infancy, with two thousand hospitalisations occurring in the first four months of life. This concentration of severe disease before the age at which infants complete their primary vaccination series underscores the importance of maternal immunisation in providing protection during the earliest months of life.

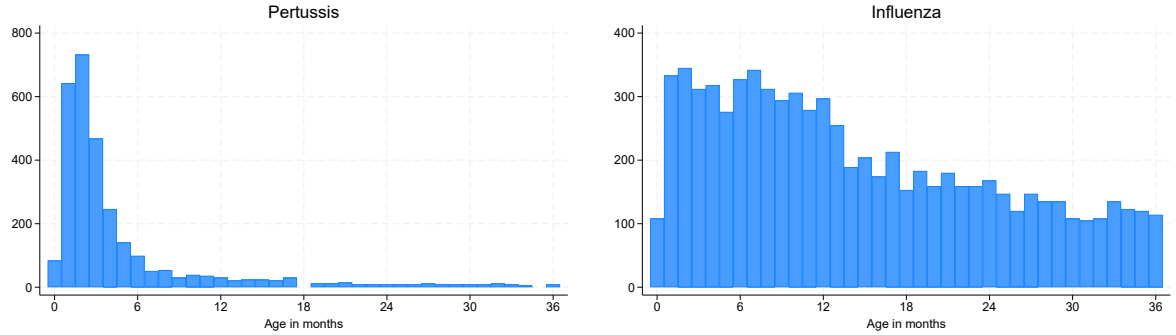

Figure 1: Hospitalisations for pertussis (left) and influenza (right) by age in months. Age in months is defined using calendar months: month 0 corresponds to the month of birth, month 1 to the following month, and so on. Following IDI confidentiality rules, all counts are subject to random rounding to base three; missing bars indicate suppressed values (fewer than six cases).

Influenza is another major cause of respiratory illness and hospitalisation. Seasonal influenza viruses circulate globally, with annual epidemics of varying intensity. It has been estimated that nearly 10 % of the world's population is affected by influenza annually, with about half a million deaths each year. Older adults, children under four years, and pregnant women are at highest risk of complications resulting from influenza infection (Javanian et al., 2021). Figure 1 (right panel) shows the number of hospitalisations by month of age in New Zealand. In contrast to pertussis, influenza hospitalisations are spread more evenly across early childhood, with similarly high numbers throughout the first three years of life. Nevertheless, infancy remains a particularly important period, as hospitalisations in children under one year outnumber those in older children.

2.3 Maternal immunisations

Vaccination during pregnancy has two potential benefits. First, it protects women against infectious diseases during pregnancy and, as a consequence, shields the fetus from congenital infections and other harmful effects. Second, it protects the infant in the first months of life, before childhood immunisations can be administered and the immune system is fully developed. This protection is achieved because vaccination during pregnancy stimulates the production of maternal antibodies. These antibodies are transferred to the fetus via the placenta and, after

birth, through breastfeeding, thereby providing passive immunity in early life (Etti et al., 2022).

Maternal immunisation against pertussis and influenza is recommended in many countries, including the United States and several European countries (CDC, 2024; Properzi et al., 2024). In New Zealand, maternal immunisations are publicly funded and recommended as part of routine prenatal care. Pertussis protection is provided through the Tdap vaccine, which covers tetanus, diphtheria, and pertussis. For pregnant women, pertussis vaccination has been in place since 2013, initially funded when administered between 28 and 38 weeks' gestation and, since 2019, available at any time during the second or third trimester. Influenza vaccination has been funded since 2010, available in any trimester, with advice to vaccinate from 1 April ahead of the usual May-September influenza season. Since June 2021, COVID-19 vaccination has been recommended during pregnancy (Health New Zealand, 2025b).

Evidence from randomised controlled trials and observational studies shows that maternal immunisation provides substantial protection for infants. For pertussis, vaccine effectiveness in infants of immunised mothers is estimated at 69-91 % for preventing disease, 91-94 % for preventing hospitalisation, and around 95 % for preventing death (Vygen-Bonnet et al., 2020). For influenza, maternal vaccination reduces the risk of infection by 48 % and associated hospitalisations by 72 % (Nunes and Madhi, 2018).

2.4 Maternal immunisation coverage

Figure 2 presents trends in the share of pregnant women receiving pertussis and influenza vaccines, highlighting persistent gaps in maternal immunisation coverage. Uptake increased steadily in the years following the introduction of these vaccines, reaching 44.8 % for pertussis and 33.5 % for influenza in 2019. While pertussis uptake remains relatively stable in subsequent years, influenza uptake peaks in 2020 before declining thereafter. In contrast to maternal immunisation, childhood immunisation uptake in New Zealand has generally been much higher. Before the pandemic, typically over 90 % of children were considered fully immunised at age 12 months (Health New Zealand, 2025a), although coverage declined during the pandemic due to delays and disruptions (Iusitini et al., 2024).

A limitation of the data is that maternal immunisations were not fully recorded in the register in the initial years, leading to underestimation of uptake. In their analysis of immunisation coverage in New Zealand, Howe et al. (2020) address this by supplementing registry data with two additional sources that capture immunisation events: a claims dataset containing fee-for-service payments made to general practices (including vaccination administration) and a pharmaceutical dataset with payment information from community pharmacies (including subsidised vaccine dispensings). For births in 2013, Howe et al. (2020) report coverage of 11.2 % for influenza and 10.2 % for pertussis, whereas registry data used in this study record 0 % and 0.3 %, respectively. By 2015, the gap had narrowed substantially: 17.9 % vs. 19.5 % for influenza and 17.1 % vs. 20.5 % for pertussis. In 2018, the estimates remain similar across the two data sources, at 28.0 % vs. 30.8 % for influenza and 41.2 % vs. 43.6 % for pertussis. This comparison suggests that recording of maternal immunisations was largely incomplete immediately after their introduction but improved quickly in the following years. For this reason, and to focus on a period when maternal immunisations were widely available, I restrict the analysis of birth-order effects on maternal immunisations to pregnancies with deliveries from 2015 onwards.

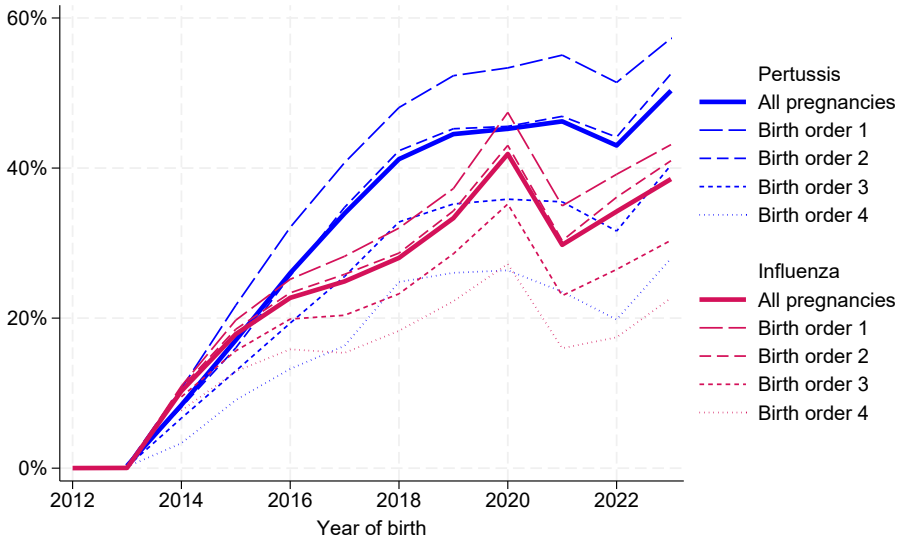

Figure 2: Maternal immunisation uptake by year and birth order

Figure 2 also displays vaccine uptake by birth order, showing that at each point in time immunisation rates are higher for first pregnancies than for second, third, or fourth pregnancies for both pertussis and influenza vaccines. While these differences could be attributed to birth-order effects, they may also reflect variation between families. For example, larger families may have different characteristics from those with only one child, potentially affecting immunisation rates. Therefore, the birth order analysis in this paper relies on within-family comparisons only.

2.5 Econometric approach

To examine how birth order relates to maternal and child outcomes, I estimate the following regression model for child or pregnancy i using ordinary least squares (OLS):

$$Y_i = \alpha + \sum_{j=2}^{4} \beta_j \, I(Birth\ order_i = j) + \gamma \, X_i + \delta_{m(i)} + \epsilon_i, \tag{1}$$

where Y_i denotes the outcome and $Birth\ order_i$ indicates birth order up to four, with children of higher birth order excluded. The omitted group is first-born children, so the coefficients β_j capture differences in outcomes between later-born children (or pregnancies) and the first-born. The estimation sample is restricted to mothers with a first birth and at least one subsequent birth in the analysis period. I exclude multiple births so that pregnancy order coincides with birth order.

Control variables X_i include an indicator for sex and year-by-month of birth indicators to allow for cohort effects. Mother fixed effects $\delta_{m(i)}$ ensure that identification relies solely on within-family variation. This approach accounts for all time-invariant family-level confounders, such as parental characteristics and maternal age at first birth. ϵ_i is the remaining error term.

Due to data availability, the observation periods differ across outcomes. For maternal immunisation uptake, I restrict the analysis to births from 2015-2023, when both maternal vaccines were readily available and reliably recorded in the immunisation register. Childhood immunisation status at age 12 months is observed for births between July 2007 and June 2022. The

analyses of childhood hospitalisations and birthweight cover births from 2000-2023. As supplementary analyses, I also examine prenatal health care using data from the national maternity collection for births between 2008 and 2021, although missing data mean that this information is not available for all births in this period.

3 Results

3.1 Maternal and childhood immunisation

Table 1 shows birth-order effects on maternal immunisations. Compared to the first pregnancy, the probability that a mother receives a pertussis and influenza vaccine is 7 and 1.4 percentage points lower at the second pregnancy. The probability decreases further for the third (-11.4 and -4.4 percentage points) and fourth pregnancy (-16 and -9.6 percentage points). The magnitude of these effects is large, given the mean uptake rates of 42.7 % for maternal pertussis and 32.3 % for maternal influenza immunisation in the analysis sample. The smaller effects for influenza may reflect differences in availability, as influenza vaccines depend on seasonal supply.

The estimated effects are smaller than the raw differences in uptake by birth order depicted in Figure 2. Across 2015-2023, maternal pertussis vaccination uptake was 46 % at first and 21 % at fourth pregnancies, a raw gap of 25 percentage points. By contrast, the estimated coefficient for fourth birth order implies a 16 percentage point lower uptake relative to first pregnancies. This suggests that part of the raw birth-order gradient reflects differences between families rather than a birth-order effect.

Table 1: Effects of birth order on immunisations

	(1) Maternal Pertussis	(2) Maternal Influenza	(3) All infant immunisations
Birth order 2	-0.070^{***}	-0.014^{***}	-0.019^{***}
	(0.004)	(0.004)	(0.001)
Birth order 3	-0.114^{***}	-0.044^{***}	-0.036^{***}
	(0.007)	(0.007)	(0.002)
Birth order 4	-0.160^{***}	-0.096^{***}	-0.057^{***}
	(0.012)	(0.011)	(0.004)
N	208,632	208,632	496,485
Mean	0.427	0.323	0.915

Notes: Regressions include mother fixed effects, year-by-month of birth fixed effects, and a female indicator. The mean of the dependent variable is displayed at the bottom of the table. Standard errors in parentheses are clustered at the mother level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 1 also reports birth-order effects on childhood immunisation. These effects are smaller than for maternal uptake, but, as with maternal immunisation, higher birth order is negatively associated with childhood immunisation. Second-born children are 1.9 percentage points less likely to be fully immunised, with the gap widening for third-born (–3.6) and fourth-born (–5.7) siblings. The findings for childhood immunisation uptake are consistent with Pruckner et al. (2021), who likewise report lower vaccine uptake among later-born children using administrative data from Austria. As both maternal and childhood immunisation rates decline with birth order,

the results imply that later-born children receive substantially less protection against infectious diseases in early life.

3.2 Hospitalisations for infectious diseases

Estimation results for the effects of birth order on infant hospitalisations, shown in Table 2, highlight the importance of protection against infectious disease. Later-born children have significantly higher hospitalisation rates for pertussis and influenza during their first year of life. Note that, as with the immunisation outcomes, the results are estimated using linear probability models, but the coefficients and standard errors multiplied by 100,000 for ease of interpretation and readability. On average, there are 124 infant hospitalisations for pertussis per 100,000 children. Relative to first-borns, the rate is higher by 46 per 100,000 among second-born children, 92 among third-borns, and 109 among fourth-borns. The effects are similar when the analysis is restricted to infections occurring within the first three months of life, a period before infants can complete the full vaccination schedule for pertussis.

Results for infant influenza hospitalisations follow a similar pattern. Higher birth order is associated with substantially higher hospitalisation rates, and the magnitude of the effect increases with birth order. Over the full infancy period, the point estimates for influenza are larger than those for pertussis, likely reflecting influenza's higher incidence.

Table 2: Effects of birth order on infant hospitalisations

	Pertussis		Influenza		RSV	
	(1) ≤12 months	(2) ≤3 months	(3) ≤12 months	(4) ≤3 months	(5) ≤12 months	(6) ≤3 months
Birth order 2	46.3***	35.1**	58.6***	51.6***	1252.4***	857.5***
	(13.3)	(11.5)	(17.7)	(9.1)	(44.6)	(30.3)
Birth order 3	92.3***	84.2***	121.4***	79.7***	1857.9***	1226.1***
	(26.9)	(23.5)	(35.9)	(18.5)	(86.6)	(59.2)
Birth order 4	109.4*	83.4*	220.5***	100.3**	2486.5***	1553.1***
	(43.8)	(37.9)	(60.3)	(31.5)	(141.4)	(93.8)
N	875,100	875,100	875,100	875,100	875,100	875,100
Mean	124.1	91.5	236.2	70.6	1612.3	770.7

Notes: Infant hospitalisations for pertussis (columns 1-2), influenza (3-4) and RSV (5-6) in the first 12 and 3 months of life. Coefficients and Standard errors scaled to per 100,000 children. Regressions include mother fixed effects, year-by-month of birth fixed effects, and a female indicator. The mean of the dependent variable is displayed at the bottom of the table. Standard errors in parentheses are clustered at the mother level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

An important question with these results is whether the higher hospitalisation rates for later-born children are driven by the lower maternal immunisation uptake. To address this, I examine hospitalisations for RSV. A maternal RSV vaccine has recently been approved in some countries but is not yet available in New Zealand. Table 2 shows large birth-order effects for RSV, indicating that differences in maternal immunisation are unlikely to be the sole explanation. The coefficients are substantially larger than those for pertussis or influenza, reflecting that RSV is a more common cause of infant hospitalisation.

Another possible explanation is that later-born children are in poorer health at birth, which could increase their susceptibility to infections and thereby contribute to higher hospitalisation rates in infancy. However, analysis of birthweight in Table 4 suggests the opposite: later-born children have higher birthweights, consistent with previous evidence that they are on average

healthier at birth (Björkegren and Svaleryd, 2023; Brenøe and Molitor, 2018; Pruckner et al., 2021). Taken together, these results suggest that underlying differences in average health status at birth are unlikely to account for the observed birth-order gradients in hospitalisation.

A plausible factor is differences in exposure to infectious diseases. Later-born children are more likely to be exposed because older siblings can bring infections home from childcare or school. This increased exposure likely contributes to the higher hospitalisation rates observed in early life. Consistent with the patterns for pertussis, influenza, and RSV hospitalisations, previous research has shown that younger siblings have higher hospitalisation rates for respiratory conditions and receive more medications for contagious diseases in infancy (Daysal et al., 2021; Pruckner et al., 2021). These findings underscore the importance of maternal and childhood immunisation in mitigating the heightened infection risks faced by later-born children.

3.3 Mechanisms

One possible explanation for the decline in maternal immunisation with birth order is that mothers may believe protection from a vaccine received during an earlier pregnancy wanes only slowly, and thus remains sufficient for a subsequent child (even though immunisation is recommended at each pregnancy). For mothers with at least three pregnancies, this belief would imply that some skip vaccination during the second pregnancy because they consider the protection from the first still adequate, but then choose to be immunised again at the third pregnancy once they believe the earlier protection to have diminished.

Table 3: Effects of birth order on maternal immunisations

	Immunised at first pregnancy		Controlling for hospitalisations	
	(1) Pertussis	(2) Influenza	(3) Pertussis	(4) Influenza
Birth order 2	-0.463^{***}	-0.498^{***}	-0.071^{***}	-0.014^{**}
	(0.014)	(0.015)	(0.005)	(0.005)
Birth order 3	-0.513^{***}	-0.531^{***}	-0.114^{***}	-0.040^{***}
	(0.026)	(0.027)	(0.009)	(0.009)
Birth order 4			-0.155^{***}	-0.106^{***}
			(0.016)	(0.015)
Previous pregnancy hospitalisation			-0.007	-0.009^{*}
			(0.004)	(0.004)
N	15,243	11,724	151,998	151,998

Notes: Regressions include mother fixed effects, year-by-month of birth fixed effects, and a female indicator. The mean of the dependent variable is displayed at the bottom of the table. Standard errors in parentheses are clustered at the mother level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

To assess this hypothesis, I restrict the sample to mothers who receive a maternal vaccine during their first pregnancy and who had at least two subsequent pregnancies. If beliefs about slowly waning protection were driving the pattern, vaccine uptake should be higher in the third pregnancy than in the second. The results, reported in Table 3, show that uptake at the third pregnancy is even lower than at the second. For example, maternal pertussis vaccine uptake decreases by 46 percentage points at the second pregnancy and by 51 percentage points at the third, relative to the first pregnancy (which, by construction, has 100 % uptake in this sample). This pattern indicates that beliefs about gradually waning protection from an earlier vaccination cannot fully account for the decline in uptake with birth order.

A second potential explanation for the decline in maternal immunisation with birth order is adverse experiences from earlier vaccinations. Although the medical literature indicates that severe side effects are very rare, some mothers may still associate immunisation with negative experiences during a previous pregnancy. To test this, I include an indicator from the National Maternity Collection for whether the mother was hospitalised during the preceding pregnancy (excluding the delivery event). Results in Table 3 suggest that maternal immunisation decreases if there was a previous hospitalisations, but the effect is small and statistically significant only for influenza. More importantly, the estimated effects of birth order are virtually unchanged.

Table 4: Effects of birth order on prenatal health care utilisation and birth weight

	Prenatal health care visits				Ultrasounds	Birth weight
	(1) 1^{st} trimester	(2) 2^{nd} trimester	(3) 3^{rd} trimester	(4) Total	(5)	(6)
Birth order 2	-0.060^{***}	-0.114^{***}	-0.470^{***}	-0.609^{***}	-0.323^{***}	152.666^{***}
	(0.007)	(0.010)	(0.017)	(0.023)	(0.009)	(1.641)
Birth order 3	-0.189^{***}	-0.197^{***}	-0.647^{***}	-1.009^{***}	-0.661^{***}	203.463^{***}
	(0.013)	(0.020)	(0.032)	(0.045)	(0.017)	(2.985)
Birth order 4	-0.324^{***}	-0.338^{***}	-0.788^{***}	-1.412^{***}	-1.009^{***}	243.599^{***}
	(0.021)	(0.031)	(0.051)	(0.072)	(0.026)	(4.723)
N	331,758	331,758	343,011	351,681	399,363	876,231
Mean	1.160	2.310	6.302	9.538	3.798	3463.228

Notes: Regressions include mother fixed effects, year-by-month of birth fixed effects, and a female indicator. The mean of the dependent variable is displayed at the bottom of the table. Standard errors in parentheses are clustered at the mother level. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$.

Finally, I examine other aspects of health care utilisation during pregnancy. Table 4 shows clear birth-order effects on both prenatal health care visits and ultrasound scans. Compared to first-borns, mothers have 0.61 fewer prenatal visits and 0.32 fewer ultrasounds at the second pregnancy, with the differences widening to 1.41 and 1 fewer, respectively, by the fourth pregnancy. These findings are consistent with previous research on prenatal health care (Brenøe and Molitor, 2018; Buckles and Kolka, 2014; Lehmann et al., 2018) and points to two mechanisms. First, reduced engagement with the health care system implies fewer opportunities for health professionals to recommend or administer maternal vaccinations. Second, the results suggest a broader change in parental behaviour, with lower (time) investment in later pregnancies, consistent with previously documented differences in parental investment during childhood.

4 Conclusion

This study provides new evidence on the role of maternal immunisation in protecting infants against infectious diseases, particularly pertussis and influenza, in early life. Using administrative data from New Zealand, I show that vaccine uptake during pregnancy declines with each subsequent pregnancy. Childhood immunisation also decreases with birth order, further reducing the protection of later-born children compared with their older siblings. At the same time, later-born children face a higher risk of infection, leading to significantly higher hospitalisation rates in early life.

Taken together, this means that the children who would benefit most from maternal immunisation are also those least likely to receive it. This highlights that policy efforts to raise

maternal immunisation uptake could be particularly impactful if they focus on later pregnancies. Strengthening uptake in this group could substantially reduce preventable infections and hospitalisations in early life.

A limitation of this study is that it cannot fully explain why maternal immunisation decreases with each pregnancy. However, a parallel decline in antenatal care, including health care visits and ultrasounds, points to broader changes in parental behaviour, consistent with prior evidence that parental investment in childhood tends to decline with birth order.

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