# Effect of measles outbreak on vaccination uptake

by

Thomas Schober

November 2018

Corresponding author: thomas.schober@jku.at

**Christian Doppler Laboratory**
**Aging, Health and the Labor Market**
cdecon.jku.at

**Johannes Kepler University**
**Department of Economics**
**Altenberger Strasse 69**
**4040 Linz, Austria**

# Effect of measles outbreak on vaccination uptake

Thomas Schober*

November 5, 2018

## Abstract

This paper explores the effects of a measles outbreak on vaccination uptake in Austria, using administrative data with individual-level information on childhood vaccinations. I define a treatment group of children affected by the outbreak, and compare them with a control group of earlier-born children who are unaffected. Twelve months after the outbreak, the vaccination rate of the treatment group is 2.5 (first dose of the measles, mumps and rubella vaccine) and 4 (second dose) percentage points higher than the corresponding rates of the control group. The results do not indicate that families at increased risk respond more strongly, suggesting that the outbreak changed the perceived value of vaccinations across the whole population. Findings also reveal heterogeneity in the response of families based on the parents' level of education, indicating that parents with higher education levels absorb new information more rapidly.

*Keywords:* vaccination, measles outbreak, health behaviour
*JEL classification:* I12, I18, H42, H51

---

[*] Thomas Schober, Johannes Kepler University of Linz, Department of Economics, Christian Doppler Laboratory for Aging, Health, and the Labor Market, Altenberger Straße 69, 4040 Linz, Austria; e-mail address: thomas.schober@jku.at. For helpful comments and discussions, I would like to thank Gerald J. Pruckner, participants of the 2018 Lunch Time Seminar at the University Linz, the 2018 Conference of the European Health Economics Association (Maastricht) and the 2018 Annual Meeting of the Austrian Economic Association (Vienna). The financial support of the Austrian Federal Ministry of Science, Research and Economy, and the National Foundation for Research, Technology and Development is gratefully acknowledged.

# 1 Introduction

Measles outbreaks continue to occur in a number of European countries. Between July 2016 and June 2017, the European Centre for Disease Prevention and Control registered more than 10,000 cases, and 22 deaths were attributed to measles in the European Economic Area (ECDC, 2017). Vaccination is an effective way to prevent the spread of the disease. However, vaccination coverage in many countries is suboptimal, and below the WHO target rate of 95 %. Achieving this rate would ensure interruption of transmission chains and herd immunity in the population (WHO, 2014).

One reason for low vaccine uptake is safety concerns. In surveys, parents who decline vaccinations for their children frequently state as reasons their fear of adverse side effects such as asthma, allergies, and autism (Brown et al., 2010; Yaqub, Castle-Clarke, Sevdalis, and Chataway, 2014). Related concerns include worries that combination vaccinations, such as the combined measles, mumps, and rubella (MMR) vaccine, lead to an 'immune overload' on the child's developing immune system, leaving the child susceptible to other infections (Hulsey and Bland, 2015). A second reason for non-vaccination is the perceived value of immunisation. A lack of general awareness about childhood diseases, low perceived severity of the illness, and an underestimated risk of infection are factors that make parents decline vaccinations (Brown et al., 2010). In this context, outbreaks of childhood diseases can be interpreted as information shocks, as corresponding media coverage is expected to increase public awareness substantially. Epidemics also affect the objective risk of contracting the disease, as the likelihood of encountering an infected person increases in such situations. Outbreaks may therefore increase vaccination coverage by changing families' risk perceptions.

I explore the effects of a measles outbreak in 2008 on vaccination uptake in Austria. Using administrative data with individual-level information on childhood vaccinations allows for a precise assessment of the decisions on whether vaccination is necessary, and when. I find that the measles outbreak substantially increases the uptake of the MMR vaccine. While the effect is strongest immediately after the outbreak, the coverage rate of affected children is 2.5 to 4 percentage points higher than that of unaffected children even after 12 months. Under rational protection behaviour, one would expect a stronger effect on families at increased risk, because a higher risk provides greater incentives for susceptible individuals to vaccinate (Philipson, 2000). However, I do not find stronger effects on families in communities that actually contracted measles. Furthermore, I do not find significant differences between the effect on first and higher order births, with a increase in risk due to older siblings in childcare facilities.

Existing empirical evidence on the effects of outbreaks on vaccination uptake is rare. Philipson (1996) provides the only known evaluation concerning measles, investigating the effect of measles cases with focus on the age at which children receive their first MMR vaccine. Philipson uses variation in cases during the 1989–1991 epidemic across the United States and data from 1991 National Health Interview Survey to show that an increase in disease incidence reduces this age significantly. Additional evidence on disease outbreaks comes from the analysis of aggregate data on pertussis epidemics, but uncovers mixed results. Wolf et al. (2014) do not find statistically significant effects of a pertussis outbreak on infant vaccinations in Washington State. In contrast, Oster (2018) uses county-level variations on disease incidence and vaccine uptake across the United States, and finds that outbreaks decrease the share of unvaccinated children entering kindergarten.

Related literature on measles explores vaccination decisions in the wake of the controversial study linking the MMR vaccine to the development of autism in children.[1] If families trade off the value of vaccines against safety, such a controversy can also be interpreted as an information shock that may influence vaccine uptake behaviour. Contrary to disease outbreaks, controversies regarding vaccine safety can be expected to decrease uptake. Accordingly, Anderberg, Chevalier, and Wadsworth (2011), and Chang (2018) find significant declines in MMR uptake in the United Kingdom and the United States as a consequence of the autism controversy. Both studies also analyse differential responses based on parents' education, suggesting a faster decline in vaccinations among highly educated populations.

## 2 Background to measles and vaccination

Measles is a highly contagious viral disease which is primarily transmitted via airborne respiratory droplets. The first symptoms start after a 10–12 day incubation period, and often include fever, coryza, cough and conjunctivitis. The characteristic measles rash usually develops 2–4 days after the onset of fever, and infection is considered contagious from 5 days before to 4 days after its onset. Serious complications, such as acute encephalitis and subacute sclerosing panencephalitis (SSPE), a severe degenerative disease of the central nervous system, are rare. More common complications include otitis media, pneumonia, and diarrhoea. Additionally, measles can suppress the immune system, and thereby increase a patient's susceptibility to other infectious diseases. Overall, the fatality rate is 1–3 per 1,000 cases, and is highest in children

---

[1] Analysing the data of 12 children, Wakefield et al. (1998) speculated that administration of the MMR vaccine may lead to autism. The study received substantial attention and media coverage in the following years, although other studies could not confirm a causal link (Demicheli, Jefferson, Rivetti, and Price, 2005). Following an investigation by the British General Medical Council, the original study was retracted in 2010, concluding that several elements of the paper were incorrect (The Editors of The Lancet, 2010).

under the age of five and among immunocompromised individuals (ECDC, 2018a).

Measles vaccination is effective in preventing the disease, and is considered to be one of the most cost-effective health interventions ever developed (Perry and Halsey, 2004). Before a vaccine became available in the 1960s, measles was responsible for 48,000 hospitalisations and 400–500 deaths per year in the United States alone (CDC, 2018). Austria introduced nationwide measles vaccinations in 1974, and since 1994, it uses the combined vaccine against measles, mumps, and rubella (Rosian and Habl, 2003). Around the time of the measles outbreak in 2008, the national vaccination schedule recommended that children get two doses of the MMR vaccine in their second year of life, with an interval of at least one month. Recommended childhood vaccines for other diseases include the 6-in-1 vaccine (diphtheria, tetanus, pertussis, polio, Haemophilus influenzae type b, and hepatitis B), with three doses in their first year and a fourth dose in the second year, and two or three doses against rotavirus infections in the first six months. Pneumococcal vaccines were also recommended, but were not included in the free-of-charge vaccination programme (Oberster Sanitätsrat, 2008).

Implementation and organization of vaccinations are carried out by the nine federal states in Austria. In Upper Austria, childhood vaccinations are supported by the regional government, which distributes books with vaccination vouchers among families. With these vouchers, families can receive vaccines at pharmacies and vaccinations from physicians free of charge. The book includes vouchers for recommended infant and childhood vaccines, including two MMR doses. Additionally, public health officers administer vaccinations in schools and district administrative centres. Austria had a relatively low vaccination uptake rate before the outbreak in 2008. In 2007, the vaccination rate for measles among children aged two was 79 %, the lowest among all OECD countries. The estimated vaccination rate for pertussis was 85 %, also substantially below the OECD average of 93.5 % (OECD, 2009).

## 3 The outbreak

The measles outbreak in Austria originated in an anthroposophic school in Salzburg in March 2008, with a visiting student from Switzerland considered as the probable source case. The number of measles cases rose quickly from nine in the second week, to a cumulative number of 90 cases in the fourth week of March. In total, there were 448 reported cases in Austria in 2008, compared to 20 in 2007. Most of the cases had an epidemiological link to the outbreak in Salzburg, and among the nine federal states in Austria, Salzburg (223 cases) and the neighbouring state of Upper Austria (131 cases) were worst affected (WHO, 2017; Schmid et al., 2010). Seventy-four patients were hospitalised because of complications, or severe disease progression, but there were no reported cases of encephalitis or deaths (EUVAC.NET, 2009).

At the onset of the outbreak, public health authorities implemented several measures to contain the spread of the disease. This included the temporary closure of the anthroposophic school where the outbreak originated, information campaigns, free vaccination in schools, temporary exclusion of unvaccinated children from schools, and free post-exposure prophylaxis for all susceptible exposed persons (ECDC, 2008). Most measles cases were reported in March and April 2008, and the policy measures are believed to have contributed to the rapid decline in new infections in the following months.

Public awareness and response to the outbreak potentially depends on media coverage discussing cases and consequences of the infections. In the empirical analysis, I focus on vaccination behaviour in Upper Austria, and therefore examine the coverage of the measles outbreak in Oberösterreichische Nachrichten, one of the largest regional newspapers in the state of Upper Austria. The first article on the subject was published on April 2, 2008, and reported an ongoing measles epidemic in Salzburg with more than 90 cases. A second article appeared on April 4, reporting a rise in the number of infected people in Salzburg, to 180. A day later, on April 5, the newspaper carried a report titled, 'Measles Epidemic reaches Upper Austria'. During the incubation period, an infected teenager participated in a billiard tournament in Linz, the capital of the state, where he most likely infected multiple unvaccinated children. Reportage on the outbreak continued in the following days and weeks, with information on new cases, but the coverage declined as the number of newly infected persons decreased.

# 4 Data

I use data from two administrative data sources, which can be linked using a unique individual identifier. Information about the relevant sample of families comes from the Austrian Birth Register. The register holds detailed information on births, and parents' socioeconomic characteristics. Data on vaccinations are provided by the regional government of Upper Austria, which subsidises recommended childhood vaccinations. For empirical analysis, I select families with children born in Upper Austria, and assess their corresponding behaviour using the vaccination data. Information on MMR vaccination is used to explore the effect of the measles outbreak. Moreover, I analyse the administration of 6-in-1 vaccines to explore potential spillover effects.[2]

Vaccination information are not perfectly recorded across all families. First, vaccinations in the three largest cities in Upper Austria are not fully included in the

---

[2] Some children receive other combinations with varying active ingredients. For simplicity, I refer to all combinations that include diphtheria and tetanus as 6-in-1 vaccines throughout the analysis.

database, because they use a separate system for monitoring vaccinations. In the analysis, I therefore exclude children born in these cities. However, children from other communities may also get their vaccinations from physicians in these cities, and are consequently not recorded in the data. Second, families may move to a different state or country with a different vaccination programme after the birth of a child. Third, families may abstain from using the book of vouchers, and use out-of-pocket payments for their vaccinations. Finally, matching across the data sources is not perfect, and some observed vaccinations could not be mapped to any family.[3] These data issues lead to an underestimation of the absolute vaccination coverage in the estimation sample. However, estimates concerning the effects of the measles outbreak are considered as largely unaffected, under the plausible assumption that the measurement error is orthogonal to the outbreak. For example, it is unlikely that many families moved to a different state because of the outbreak.

## 5 Descriptives

In order to motivate a detailed analysis of the measles outbreak, Figure 1 compares trends in the interest in measles, with the number of vaccinations over time. As a proxy for interest in the childhood disease, I use data from Google Trends, which provides an index of the volume of queries that users enter into Google's web search engine. The index shows the query share of a search term in relation to the total number of queries, and normalises the maximum share in the time period to 100. The figure displays monthly searches for the term 'measles' (in German, 'Masern') in Austria between 2004 and 2016. The spike in April 2008 clearly suggests an increased interest in measles, shortly after the start of the outbreak. Before April 2008, the displayed data indicate that the popularity of the search term varied between 1 and 7 percent of the maximum value. Another notable observation is the rapid decrease in interest in the following months, to similar levels observed before the outbreak. Later increases in popularity coincide with smaller outbreaks in Austria in 2014 and 2015 (ECDC, 2014; ECDC, 2015). Other factors leading to increased awareness could be the coverage of the death of an 18-month-old child in Germany following measles infection in February 2015, and an information campaign started by the Ministry of Health in 2014.

Figure 1 also displays the absolute number of MMR vaccines administered by physicians in the outpatient sector per month in the same time period. While the typical number varies between 1,000 and 2,000 in the months before the outbreak, there is a surge in the number of vaccinations in April 2008, indicating that the outbreak induced a substantial number of additional vaccinations in that month. Because media

---

[3] During the measles outbreak (2007–2009), 3.3 % of all MMR vaccinations could not be matched.

coverage and the increase in the number of vaccinations started in the same month, I consider April 2008 as the starting point of the measles outbreak in subsequent analysis.

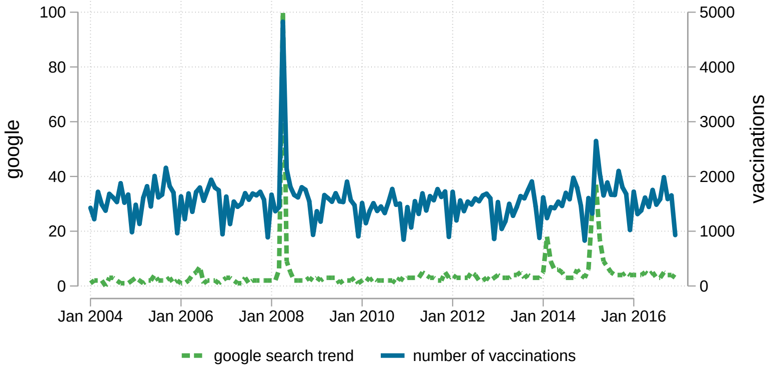

**Figure 1:** Interest in measles and the number of vaccinations over time

Figure 2 shows the number of MMR vaccinations in the second quarter of both 2007 and 2008 across children's age, and highlights the distribution of additional vaccinations after the measles outbreak. While vaccinations increase in all age groups, most additional vaccinations were accounted for by children aged between one and two years. In general, the age distribution is shaped by the Austrian vaccination schedule outlined above, recommending two MMR vaccinations in the second year of life. Apparently, a substantial number of parents postpone vaccinations until their children are older.

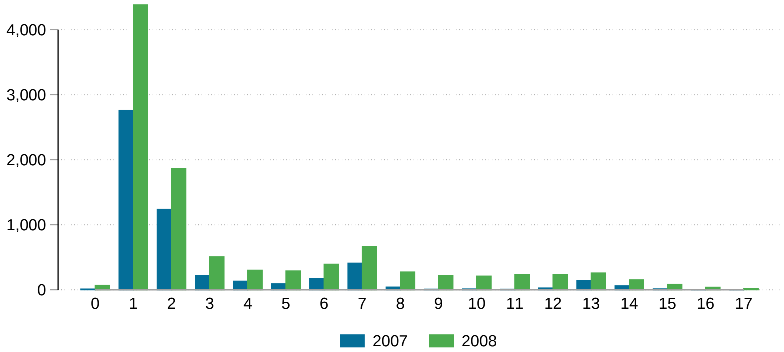

**Figure 2:** Number of MMR vaccinations for children in the second quarter of 2007 and 2008 over age

# 6 Empirical strategy

To analyse individual vaccination behaviour, I compare a treatment group of children affected by the measles outbreak, and a control group of earlier-born unaffected children. The treatment group includes children born between April 2006 and March 2007. These children are at least one year old at the beginning of the outbreak in April 2008, and therefore fall in the age group for which vaccination is recommended. I assess individual vaccination behaviour for each month to precisely analyse the impact of the outbreak over time. To present the results, I define event time $t$, and analyse the vaccination behaviour of treated children starting with $t = 1$ in April 2008 until $t = 12$ in March 2009.

The control group includes children who were born one year earlier than those in the treatment group, i.e. those born between April 2005 and March 2006. I compare the vaccination trends among children in the two groups when they are the same age. Consequently, I take the control group's vaccinations between April 2007 ($t = 1$) and March 2008 ($t = 12$) as a benchmark to estimate the effect of the measles outbreak on vaccination behaviour. The one-year gap between the considered birth cohorts should ensure that the comparison is not affected by potential seasonality in vaccination behaviour.

I use a linear probability model to estimate the baseline effect of the measles outbreak:

$$v_{it} = \beta_1 T_i + \gamma B_i + \epsilon_i, \tag{1}$$

where $v_{it}$ is the vaccination outcome of child $i$ at time $t$, $T_i$ is a dummy variable indicating if the child belongs to the treatment group, and $B_i$ is a vector of control variables. I estimate equation 1 separately for months $t = 1$ to $t = 12$. For the main outcomes, I use dummy variables indicating if the child gets the first or the second MMR vaccine until month $t$. Additionally, the 6-in-1 vaccine is used as an outcome to explore potential spillover effects. I include a full set of dummy variables considering a child's age at $t = 1$ in months, the child's sex, and mothers' education level as control variables. In further estimations, interaction terms between treatment and family characteristics are included to explore heterogeneity in response to the outbreak.

As there is no random assignment to treatment and control groups, the identification of causal effects of the measles outbreak in this framework is based on the assumption that the groups are comparable. More precisely, I assume that the treatment group would have behaved similarly to the control group in absence of the outbreak, an assumption that is untestable. However, I compare the family characteristics and vaccination behaviour before the outbreak to explore potential differences.

Table 1 summarises corresponding results for the 21,110 children in the sample. The comparison reveals similar vaccination behaviour in families before the outbreak ($t = -1$ relates to March 2007 for children in the control group, and March 2008 for the treatment group). In the control group, 43.7 % of children received the first MMR vaccination, while 10.1 % of children received the second MMR vaccination. Vaccine uptake in the control group is within the same range (43.4 % and 9.4 %), and the differences are not statistically significant at the 5 % level. The data also indicates no significant differences in the rate of administration of 6-in-1 vaccinations, where three doses are recommended in the first year and one dose in the second year of life. The absence of a systematic difference in vaccination behaviour suggests that at least before the outbreak, there was a prevalence of similar attitudes and beliefs about the value and perceived safety of vaccines across families in control and treatment groups.

Table 1 also contrasts observable (socioeconomic) characteristics of children and their mothers. For most variables, I find very similar values in both groups. One exception is a small but statistically significant difference in children's birth weight. However, the comparison of Apgar scores[4] does not suggest a substantial gap in health between both groups when a child is born. A second statistically significant difference concerns the parents' education level, indicating a higher education level of mothers in the treatment group. I control for the education level in all estimations to allow for this potential confounder. Overall, the similar distribution of characteristics supports the plausibility of the identifying assumption, so that a comparison of the treatment and control groups should reveal the causal effect of the measles outbreak on vaccine uptake.

# 7 Main results

Estimates of the equation 1 for the first and second MMR vaccine are summarised in Figure 3, with corresponding estimation output listed in Table A2 in the web appendix. The point estimates can be interpreted as percentage point increases in vaccination uptake resulting from the measles outbreak.

The results suggest substantial and statistically significant effects on vaccination behaviour. For children in the treatment group, the probability of receiving the first MMR vaccine is 7.3 percentage points higher than that of the control group at the beginning of the measles outbreak ($t = 1$). As regards the second MMR vaccination, the highest difference can be observed around 4 to 7 months after the beginning of the outbreak. This delay in response is probably due to the required interval of at least four weeks between two MMR doses.

Over the course of 12 months, the magnitude of the point estimates declines. This indicates that the measles outbreak induced some families to prepone vaccinations. These families would have vaccinated later if the outbreak had not occurred. However,

---

[4] The Apgar score summarises the health of new-born children ranging from 0 to 10, based on skin colour, pulse rate, reflexes, activity, and respiration. In Austria, the test is done 1, 5 and 10 minutes after birth.

**Table 1:** Characteristics of children in the treatment and control groups

| | (1)<br>Control | (2)<br>Treated | (3)<br>Difference | (4)<br>p-value |
|---|---|---|---|---|
| characteristics of child | | | | |
| age (months) | 17.58 | 17.56 | −0.03 | 0.589 |
| female | 0.493 | 0.492 | −0.002 | 0.818 |
| birth order 1 | 0.443 | 0.445 | 0.003 | 0.689 |
| birth weight (gram) | 3346 | 3328 | −17 | 0.021 |
| 1-minute Apgar score | 8.78 | 8.78 | 0.01 | 0.650 |
| 5-minute Apgar score | 9.69 | 9.70 | 0.01 | 0.388 |
| 10-minute Apgar score | 9.90 | 9.91 | 0.01 | 0.082 |
| characteristics of mother | | | | |
| age at birth (years) | 28.95 | 29.06 | 0.10 | 0.156 |
| married | 0.603 | 0.594 | −0.008 | 0.208 |
| born abroad | 0.183 | 0.184 | 0.001 | 0.865 |
| community with measles cases | 0.138 | 0.140 | 0.001 | 0.769 |
| education of mother | | | | |
| low | 0.180 | 0.164 | 0.016 | 0.003 |
| medium | 0.573 | 0.575 | −0.002 | |
| high | 0.247 | 0.261 | −0.014 | |
| vaccination status at $t = -1$ | | | | |
| $1^{st}$ MMR | 0.437 | 0.434 | −0.003 | 0.635 |
| $2^{nd}$ MMR | 0.101 | 0.094 | −0.007 | 0.079 |
| $1^{st}$ 6-in-1 | 0.813 | 0.818 | 0.005 | 0.329 |
| $2^{nd}$ 6-in-1 | 0.787 | 0.790 | 0.003 | 0.608 |
| $3^{rd}$ 6-in-1 | 0.731 | 0.733 | 0.003 | 0.663 |
| $4^{th}$ 6-in-1 | 0.193 | 0.192 | −0.001 | 0.793 |
| N | 10,734 | 10,376 | | |

*Notes:* This table summarises the characteristics of children in the control (column 1) and treatment (column 2) groups from the analysis sample. Column 3 displays the difference between the mean values, while column 4 shows the p-value of a t-test for the difference between the means, and the p-value of a chi-squared test for the difference in mothers' education distribution. Education levels are categorised as compulsory education (low), vocational school and apprenticeship (medium), and a secondary school exit exam required to enter university (high). The comparison of Apgar scores is based on fewer observations because of missing data of 14 children.

after 12 months, treated families' vaccine uptake of the first and second MMR was still 2.5 and 4 percentage points higher compared to the control group, which did not experience the outbreak.

Table 2 summarises the results of several robustness checks at $t = 1$ and $t = 12$ using different specifications and samples. First, I include additional control variables to allow for observable family characteristics that may affect vaccination behaviour, namely the child's birth order and birth weight, mothers' age at birth, marital status, birth place, and an indicator if the community had measles cases during the outbreak. The results (Panel B) are virtually unchanged compared to the baseline effects, suggesting that the response to the outbreak is not affected by differences in characteristics. In a second robustness check, I restrict the analysis to a subset of children who receive a 6-in-1 vaccine before the outbreak ($t = -1$). These families therefore partici-

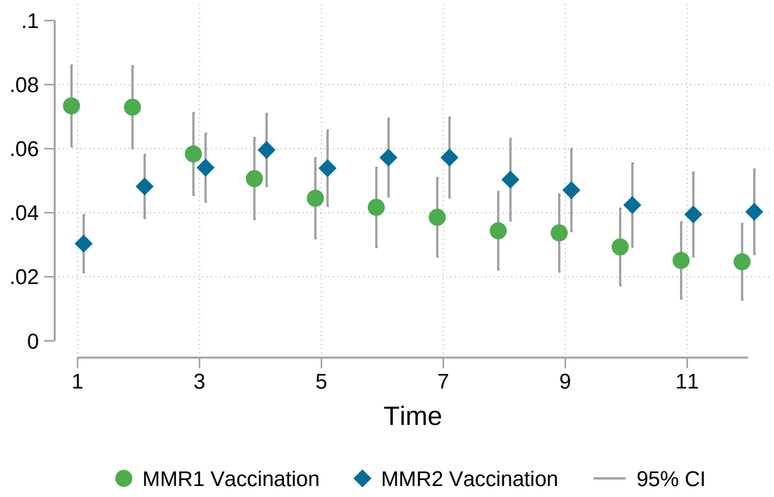

**Figure 3:** Baseline estimates of the measles outbreak. Displayed are the coefficients and 95 % confidence intervals of the treatment indicator of separate estimations. Coloured indicators are used when the child gets the first (green) and the second (blue) MMR vaccination until time $t$. Corresponding estimation output is in Table A2 in the web appendix.

pate in the public vaccination programme in general, and the vaccines administered by their family doctor are recorded in the data, but some families may refuse to receive the MMR vaccine. The estimates (Panel C) reveal very similar results compared to the baseline specification. The outbreak increases the probability of receiving the first (second) MMR vaccine by 8 (3.7) percentage points in the first month, and 2 (4.1) percentage points after 12 months.

A separate set of estimations uses only previously non-vaccinated children. By definition, effects on the full population can only be explained by changes in the behaviour of families who did not go for vaccination before the outbreak. Consequently, the results show the same response pattern obtained in the full sample (Panel D). After the outbreak, previously non-vaccinated children in the treatment group get substantially more first and second MMR doses compared to their counterparts in the control group who do not experience the outbreak.

## 8 Heterogeneity

Table 3 summarises the results from additional regressions that explore heterogeneity in response to the measles outbreak, by interacting family characteristics with the treatment indicator. For brevity, only results immediately after the outbreak ($t = 1$) and one year after ($t = 12$) the first MMR vaccination, are presented. *Panel A* explores whether the effects in the previous section are driven by communities that actually

**Table 2:** Robustness checks

| | $t = 1$ | | | $t = 12$ | | | |
|---|---|---|---|---|---|---|---|
| | (1) Estimate | (2) S.E. | (3) Mean | (4) Estimate | (5) S.E. | (6) Mean | (7) N |
| *Panel A: Baseline effects* | | | | | | | |
| $1^{st}$ MMR vaccine | 0.073*** | (0.006) | 0.523 | 0.025*** | (0.006) | 0.733 | 21110 |
| $2^{nd}$ MMR vaccine | 0.030*** | (0.005) | 0.141 | 0.040*** | (0.007) | 0.542 | 21110 |
| *Panel B: Additional control variables* | | | | | | | |
| $1^{st}$ MMR vaccine | 0.073*** | (0.006) | 0.523 | 0.024*** | (0.006) | 0.733 | 21110 |
| $2^{nd}$ MMR vaccine | 0.030*** | (0.005) | 0.141 | 0.040*** | (0.007) | 0.542 | 21110 |
| *Panel C: Sample of children with 6-in-1 vaccinations at* $t = -1$ | | | | | | | |
| $1^{st}$ MMR vaccine | 0.080*** | (0.007) | 0.639 | 0.020*** | (0.005) | 0.884 | 16981 |
| $2^{nd}$ MMR vaccine | 0.037*** | (0.005) | 0.173 | 0.041*** | (0.007) | 0.663 | 16981 |
| *Panel D: Sample of children without* $1^{st}/2^{nd}$ *MMR vaccination at* $t = -1$ | | | | | | | |
| $1^{st}$ MMR vaccine | 0.132*** | (0.006) | 0.156 | 0.044*** | (0.009) | 0.527 | 11922 |
| $2^{nd}$ MMR vaccine | 0.039*** | (0.003) | 0.048 | 0.048*** | (0.007) | 0.493 | 19043 |

*Notes:* This table summarises robustness checks using different specifications and samples. Each cell in columns 1 and 4 shows the point estimate from a separate regression, while robust standard errors are shown in columns 2 and 4. Columns 3 and 6 display the mean of the dependent variable. Baseline effects are reproduced in *Panel A*, while *Panel B* adds the child's birth order and birth weight, as well as the mothers' age at birth, marital status, birth place, and an indicator if the community had measles cases during the outbreak, as additional control variables. *Panel C* uses only children with 6-in-1 vaccinations before $t = 1$, and *Panel D* only children without the first or second MMR vaccination before $t = 1$. All regressions include controls for the child's age, sex, and mother's education level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

had measles cases during the outbreak. Knowledge of nearby cases could lead to an increased demand for vaccines because of the higher (perceived) risk of an infection. Moreover, policy measures in response to the outbreak can be expected to be more intense in affected schools and communities. The findings do not reveal stronger reactions in affected communities. At $t = 1$, the point estimate on the interaction term is negative and statistically insignificant, indicating similar effects in unaffected and affected communities immediately after the outbreak. After 12 months, the results suggest that the vaccine uptake actually increased less in affected communities, which could be explained by the fact that average vaccination rate in these communities was higher before the outbreak.

A related idea to uncover the potential impact of policy measures such as information campaigns in schools and in kindergarten is through the birth order of children. In Upper Austria, only 6.7 % of children aged up to two years were in childcare facilities in 2008. Among three to five year olds, the rate was 85.7 % (Statistik Austria, 2018). A majority of the children in the analysis sample are therefore looked after at home, while many of their older siblings (if they have any) are already in kindergarten or school. Information material distributed in public institutions, or questions regarding the vaccination status by school physicians or teachers, may lead to stronger effects among families with older siblings. However, increased vaccination in these families could also be explained by a rational response, as these families may also fear an increased risk for their younger children. *Panel B* compares first and higher order births in the analysis sample, i.e. children without and with older siblings in the family. The results do not reveal a significant heterogeneity in response to the outbreak, suggesting that the effects of the measles outbreak are not mainly driven by information campaigns in schools and kindergartens, or by perceived risk from older siblings.

There is a large body of literature on the effects of education on health and health behaviour (Lochner, 2011). Education could have an impact on how (fast) information is processed. With respect to vaccination behaviour, for example, Anderberg, Chevalier, and Wadsworth (2011) find that in the wake of the controversy linking the MMR vaccine to the development of autism, vaccination rates declined faster in areas with populations having relatively higher education levels. To analyse the effect heterogeneity with respect to education, I interact the treatment variable with the education level of the mother, categorised into the three groups: compulsory education only (low), vocational school and apprenticeship (medium), and a secondary school exit exam required to enter university (high). Results in *Panel C* suggest a distinct education gradient. Compared to mothers with low education levels, the vaccine uptake in families having mothers with medium (high) education levels increased by 5 (8.4) percentage points immediately after the outbreak. After 12 months, the education gradient decreases, and only the difference between mothers with high and low education levels remains statistically significant. These results indicate a faster reaction of mothers with medium to high education levels, which is consistent with the hypothesis that individuals with higher education levels absorb and respond to information related to health risks more quickly.

An analysis of the effect heterogeneity on the second MMR vaccine yields similar results (see Table A1 in the web appendix for estimation output). There is no statistically significant difference in the response to the outbreak with respect to birth order, and the occurrence of measles cases in the community. In contrast, I do not find a faster response for the second MMR dose among parents with higher education levels immediately after the outbreak. A plausible explanation is that the required time interval between measles vaccinations. Therefore, children without prior vaccinations cannot receive the second MMR vaccine immediately.

## 9 Spillover effects

The preceding sections show a strong effect of the measles outbreak on MMR uptake. However, there may also be effects on other vaccinations via various channels. First, the outbreak could affect the general awareness of childhood diseases and attitudes

**Table 3:** Effect heterogeneity for the first measles vaccination

| | $t = 1$ | | $t = 12$ | |
|---|---|---|---|---|
| | (1) Estimate | (2) S.E. | (3) Estimate | (4) S.E. |
| *Panel A: Measles cases in community* | | | | |
| T | $0.076^{***}$ | (0.007) | $0.030^{***}$ | (0.007) |
| T × Affected community | $-0.014$ | (0.020) | $-0.038^{*}$ | (0.017) |
| Affected community | $0.101^{***}$ | (0.014) | $0.114^{***}$ | (0.012) |
| *Panel B: Birth order of child* | | | | |
| T | $0.076^{***}$ | (0.009) | $0.025^{**}$ | (0.008) |
| T × first birth | $-0.007$ | (0.013) | 0.000 | (0.012) |
| First birth | $0.088^{***}$ | (0.009) | $0.050^{***}$ | (0.009) |
| *Panel C: Education level of mother* | | | | |
| T | 0.023 | (0.015) | 0.009 | (0.013) |
| T × Medium education | $0.050^{**}$ | (0.018) | 0.009 | (0.015) |
| T × High education | $0.084^{***}$ | (0.020) | $0.042^{*}$ | (0.019) |
| Medium education | $-0.075^{***}$ | (0.012) | $-0.044^{***}$ | (0.011) |
| High education | $-0.191^{***}$ | (0.014) | $-0.180^{***}$ | (0.013) |

*Notes:* This table summarises the estimation results on the effect heterogeneity for the first MMR vaccination at time $t = 1$ (point estimate in column 1, robust standard error in column 2) and $t = 12$ (columns 3 and 4). Each panel presents the results of separate regressions where the treatment indicator is interacted with the education level of the mother (*Panel C*), the occurrence of measles cases in the community (*Panel A*), and the birth order of the child (*Panel B*). Regressions include controls for the child's age and sex and the mother's education level. N=21,110. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$.

towards vaccination, which may lead to a general increase in vaccine uptake. Second, since children can receive several vaccines at once, a visit to the physician for the MMR vaccine decreases the opportunity cost of getting other vaccines. Third, the outbreak could also lead to a decrease in demand for other vaccines. For example, if families believe that getting many vaccines within a short period of time is dangerous, they may postpone or reject other childhood immunisations in favour of MMR. The direction and size of potential spillover effects is therefore ambiguous.

Table 4 explores spillover effects of the measles outbreak on 6-in-1 vaccinations. Analogous to the MMR vaccine, equation 1 is used to assess whether the measles outbreak had an effect on getting the four recommended 6-in-1 vaccines at time $t$. Results do not suggest spillover effects immediately after the outbreak ($t = 1$), with small and statistically insignificant point estimates. Furthermore, after 12 months, there are no effects on the uptake of the second, third, and fourth 6-in-1 dose. Only for the first 6-in-1 vaccination, the results reveal a small but statistically significant increase of 1.1 percentage points.

The vaccination schedule recommends three doses at one year of age and another at two years. Consequently, uptake of doses 1–3 is already high at $t = 1$, and increases only marginally thereafter (see columns 3 and 6 of Table 4). In contrast, many children receive their fourth 6-in-1 dose between $t = 1$ and $t = 12$, making the potential spillover effects on vaccination behaviour strongest for this outcome. I interpret the absence of a significant effect on the fourth 6-in-1 vaccination as a strong indicator for no spillover effects. Together with the estimates for doses 1–3, the results suggest that spillover effects are non-existent or negligibly small.

**Table 4:** Spillover effects on 6-in-1 vaccinations

| | $t = 1$ | | | $t = 12$ | | |
|---|---|---|---|---|---|---|
| | (1) Estimate | (2) S.E. | (3) Mean | (4) Estimate | (5) S.E. | (6) Mean |
| $1^{st}$ | 0.008 | (0.005) | 0.818 | $0.011^{*}$ | (0.005) | 0.834 |
| $2^{nd}$ | 0.006 | (0.006) | 0.792 | 0.005 | (0.005) | 0.807 |
| $3^{rd}$ | 0.005 | (0.006) | 0.740 | 0.004 | (0.006) | 0.776 |
| $4^{th}$ | −0.004 | (0.005) | 0.231 | 0.002 | (0.007) | 0.622 |

*Notes:* This table summarises the estimation results on spillover effects. Each cell in columns 1 and 4 shows the point estimate of a separate regression using the four recommended doses of the 6-in-1 vaccine as dependent variables. The values indicate whether the child gets the respective vaccine at time $t = 1$ and time $t = 12$. Corresponding to the robust standard error in columns 2 and 4, columns 3 and 6 display the mean of the dependent variable. Regressions include controls for the child's age and sex and mother's education level. N=21,110. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$.

# 10 Conclusion

In this paper, I investigate the effects of a measles outbreak on vaccination behaviour using administrative data from Austria. The outbreak increased the uptake of the MMR vaccine significantly. In making vaccination choices, families are typically assumed to weigh the benefits of protection against infectious diseases against the costs of vaccination, such as the risk of harmful side effects. In this context, I test the hypothesis that families at increased risk have stronger responses to the outbreak. This includes families living in communities that experienced measles cases during the outbreak, and children with older siblings compared to those without. The results do not reveal a large heterogeneity in responses, indicating that the outbreak and the related media coverage changed families' assessment of the value of measles vaccinations among the entire population.

In view of the growing number of outbreaks of preventable diseases, increasing the immunisation coverage is on the political agenda of many countries. Although vaccinations are often subsidised or completely free of charge, uptake is typically too low to protect individuals who are not (yet) immune. This paper suggests that informing people about measles outbreaks can increase the demand for vaccines. The knowledge of infections and their consequences may affect the public awareness of childhood diseases and the perceived benefits of vaccination.

It should be noted that during measles outbreaks, the type of information available and its manner of absorption by the population is likely to differ from usual vaccination campaigns. An outbreak is an exceptional situation and a shock to the public. However, such shocks are useful to evaluate changes in people's behaviour and gain insights into potential effects of policy actions that aim to increase vaccination coverage.

Interestingly, I find only little evidence regarding spillover effects on other vaccinations, which suggests that outbreaks do not have strong effects on the perceived benefits of vaccination in general. The findings also indicate heterogeneity in the response with respect to parents' level of education, in line with previous results on the MMR vaccine autism controversy (Anderberg, Chevalier, and Wadsworth, 2011; Chang, 2018). When compared with parents having low levels of education, those with medium to high level of education increase vaccination uptake faster, immediately after the outbreak. This indicates that the speed with which new information regarding health risks is processed is correlated to the level of education.

A limitation of the analysis is that because of the outlined estimation strategy, I only analyse the response during the 12 months after the outbreak. The analysis of long-term effects would require the selection of earlier-born cohorts as control groups. A concern regarding this approach is the potential change in vaccination attitudes and practices, which limits the plausibility of the identifying assumption when much older cohorts are compared. However, from a health policy perspective, vaccinations during early childhood are of particular interest, because the disease can be especially dangerous for young children. Most European countries therefore recommend early administration of MMR to ensure optimal protection of the population (ECDC, 2018b).

# References

Anderberg, Dan, Arnaud Chevalier, and Jonathan Wadsworth (2011). "Anatomy of a Health Scare: Education, Income and the MMR Controversy in the UK". In: *Journal of Health Economics* 30.3, pp. 515–530.

Brown, Katrina F, J Simon Kroll, Michael J Hudson, Mary Ramsay, John Green, Susannah J Long, Charles A Vincent, Graham Fraser, and Nick Sevdalis (2010). "Factors underlying parental decisions about combination childhood vaccinations including MMR: A systematic review". In: *Vaccine* 28.26, pp. 4235–4248.

CDC (2018). *Measles history*. `https://www.cdc.gov/measles/about/history.html`. [accessed 2018-07-20].

Chang, Lenisa V (2018). "Information, education, and health behaviors: Evidence from the MMR vaccine autism controversy". In: *Health Economics* 27.7, pp. 1043–1062.

Demicheli, Vittorio, Tom Jefferson, Alessandro Rivetti, and Deirdre Price (2005). "Vaccines for measles, mumps and rubella in children". In: *The Cochrane Database of Systematic Reviews* CD004407.

ECDC (2008). *ECDC Mission report. Measles outbreak in Austria. Risk assessment in advance of the EURO 2008 football championship 14-17 April 2008.* `http://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/0804_MIR_Measles_Outbreak_in_Austria.pdf`. European Centre for Disease Prevention and Control.

— (2014). *Measles and rubella monitoring, April 2014.* European Centre for Disease Prevention and Control. Stockholm.

— (2015). *Measles and rubella monitoring, April 2015.* European Centre for Disease Prevention and Control. Stockholm.

— (2017). *Bi-annual measles and rubella monitoring report, October 2017.* European Centre for Disease Prevention and Control. Stockholm.

— (2018a). *Factsheet about measles.* `https://ecdc.europa.eu/en/measles/facts/factsheet`. [accessed 2018-07-20].

— (2018b). *Vaccine Scheduler - Vaccine schedules in all countries of the European Union.* `https://vaccine-schedule.ecdc.europa.eu`. [accessed 2018-08-16].

EUVAC.NET (2009). *Measles surveillance annual report 2008.* `http://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/measles_report_2008_euvacnet.pdf`. [accessed 2017-12-18].

Hulsey, Ella and Tami Bland (2015). "Immune overload: Parental attitudes toward combination and single antigen vaccines". In: *Vaccine* 33.22, pp. 2546–2550.

Lochner, Lance (2011). "Non-Production Benefits of Education: Crime, Health, and Good Citizenship". In: *Handbook of the Economics of Education.* Ed. by Eric Hanushek, Stephen Machin, and Ludger Woessmann. Vol. 4. Amsterdam: Elsevier, pp. 183–282.

OECD (2009). *Health at a Glance 2009: OECD Indicators.* OECD Publishing.

Oberster Sanitätsrat (2008). "Impfplan 2008 - Der Impfausschuss des Oberstern Sanitätsrat hat die neuesten, evidenz-basierten Empfehlungen im Impfplan 2008 zusammengefasst". In: *Österreichische Ärztezeitung*, pp. 23–54.

Oster, Emily (2018). "Does disease cause vaccination? Disease outbreaks and vaccination response". In: *Journal of Health Economics* 57, pp. 90–101.

Perry, Robert T and Neal A Halsey (2004). "The clinical significance of measles: A review". In: *The Journal of Infectious Diseases* 189, S4–S16.

Philipson, Tomas (1996). "Private vaccination and public health: An empirical examination for US measles". In: *Journal of Human Resources*, pp. 611–630.

Philipson, Tomas (2000). “Economic epidemiology and infectious diseases”. In: *Handbook of Health Economics* 1, pp. 1761–1799.

Rosian, Ingrid and Claudia Habl (2003). *Impfungen. Ökonomische Evaluation.* ÖBIG Österreichisches Bundesinstitut für Gesundheitswesen.

Schmid, Daniela, Heidemarie Holzmann, Karin Schwarz, Sabine S Kasper, H-W Kuo, Stefan W Aberle, Monika Redlberger-Fritz, Wolfgang Hautmann, Sabine Santibanez, Annette Mankertz, Christoph König, Eva Magnet, Sandra Reichart, Stefan Meusburger, Anita Luckner-Hornischer, Alfred de Martin, Elmar Bechter, Janelle Stirling, and Franz Allerberger (2010). “Measles outbreak linked to a minority group in Austria, 2008”. In: *Epidemiology & Infection* 138.3, pp. 415–425.

Statistik Austria (2018). *Kindertagesheimstatistik 2017/18.* Wien: Verlag Österreich.

The Editors of The Lancet (2010). “Retraction–Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children”. In: *Lancet* 375.9713, p. 445.

WHO (2014). *Eliminating measles and rubella. Framework for the verification process in the WHO European Region.* World Health Organization.

— (2017). *Measles - Reported cases by country.* `http://apps.who.int/gho/data/view.main.1540_62`. [accessed 2017-12-18].

Wakefield, Andrew J, Simon H Murch, Andrew Anthony, John Linnell, David M Casson, Mohsin Malik, Mark Berelowitz, Amar P Dhillon, Michael A Thomson, Peter Harvey, Alan Valentine, Susan E Davies, and John A Walker-Smith (1998). “Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children”. In: *Lancet* 351.9103. Note: Retracted, pp. 637–641.

Wolf, Elizabeth R, Douglas Opel, M Patricia DeHart, Jodi Warren, and Ali Rowhani-Rahbar (2014). “Impact of a pertussis epidemic on infant vaccination in Washington state”. In: *Pediatrics*, pp. 456–464.

Yaqub, Ohid, Sophie Castle-Clarke, Nick Sevdalis, and Joanna Chataway (2014). “Attitudes to vaccination: A critical review”. In: *Social Science & Medicine* 112, pp. 1–11.

# A Web appendix

**Table A1:** Effect heterogeneity for the second measles vaccination

| | $t = 1$ | | $t = 12$ | |
|---|---|---|---|---|
| | (1)<br>Estimate | (2)<br>S.E. | (3)<br>Estimate | (4)<br>S.E. |
| *Panel A: Measles cases in community* | | | | |
| T | $0.032^{***}$ | (0.005) | $0.044^{***}$ | (0.007) |
| T × Affected community | $-0.015$ | (0.014) | $-0.032$ | (0.019) |
| Affected community | $0.028^{**}$ | (0.010) | $0.094^{***}$ | (0.013) |
| *Panel B: Birth order of child* | | | | |
| T | $0.030^{***}$ | (0.006) | $0.046^{***}$ | (0.009) |
| T × first birth | 0.001 | (0.009) | $-0.014$ | (0.013) |
| First birth | $0.041^{***}$ | (0.006) | $0.098^{***}$ | (0.009) |
| *Panel C: Education level of mother* | | | | |
| T | $0.024^{*}$ | (0.012) | 0.005 | (0.016) |
| T × Medium education | 0.004 | (0.013) | 0.034 | (0.018) |
| T × High education | 0.014 | (0.014) | $0.061^{**}$ | (0.021) |
| Medium education | $-0.009$ | (0.009) | $-0.065^{***}$ | (0.013) |
| High education | $-0.049^{***}$ | (0.009) | $-0.185^{***}$ | (0.015) |

*Notes:* This table summarises the estimation results on the effect heterogeneity for the second MMR vaccination at time $t = 1$ (point estimate in column 1, robust standard error in column 2) and $t = 12$ (columns 3 and 4). Each panel presents the results of separate regressions where the treatment indicator is interacted with the education level of the mother (*Panel C*), the occurrence of measles cases in the community (*Panel A*), and the birth order of the child (*Panel B*). Regressions include controls for the child's age and sex and the mother's education level. N=21,110. $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$.

**Table A2:** Effects of measles outbreak on vaccination uptake

| | $t = 1$ | $t = 2$ | $t = 3$ | $t = 4$ | $t = 5$ | $t = 6$ | $t = 7$ | $t = 8$ | $t = 9$ | $t = 10$ | $t = 11$ | $t = 12$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Panel A: Child has had the first MMR vaccination* | | | | | | | | | | | | |
| T | $0.073^{***}$ | $0.073^{***}$ | $0.058^{***}$ | $0.051^{***}$ | $0.045^{***}$ | $0.042^{***}$ | $0.039^{***}$ | $0.034^{***}$ | $0.034^{***}$ | $0.029^{***}$ | $0.025^{***}$ | $0.025^{***}$ |
| | (0.006) | (0.007) | (0.007) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Mean | 0.523 | 0.573 | 0.615 | 0.643 | 0.663 | 0.680 | 0.694 | 0.705 | 0.710 | 0.719 | 0.724 | 0.733 |
| *Panel B: Child has had both doses* | | | | | | | | | | | | |
| T | $0.030^{***}$ | $0.048^{***}$ | $0.054^{***}$ | $0.060^{***}$ | $0.054^{***}$ | $0.057^{***}$ | $0.057^{***}$ | $0.050^{***}$ | $0.047^{***}$ | $0.042^{***}$ | $0.039^{***}$ | $0.040^{***}$ |
| | (0.005) | (0.005) | (0.005) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.007) | (0.007) | (0.007) | (0.007) |
| Mean | 0.141 | 0.181 | 0.225 | 0.269 | 0.313 | 0.355 | 0.399 | 0.435 | 0.456 | 0.486 | 0.513 | 0.542 |

*Notes:* This table summarises estimation results of the equation 1. Panel A reports the effects of the measles outbreak on the receipt of the first MMR vaccination, while Panel B reports the effects of receiving the second MMR dose. The mean of the dependent variable is displayed at the bottom of each panel. Regressions include controls for the child's age and sex and the mother's education level. N=21,110. Robust standard errors are shown in parentheses. $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$.