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Parental Separation and Its Impact on Childhood Vaccination: Evidence from Italy

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Abstract

Research on the effects of parental separation on children's socioeconomic outcomes is extensive, yet little is known about how family disruptions impact adherence to vaccination schedules. This study addresses this gap by investigating the association between parental separation and children's vaccination coverage, using a unique dataset on Italian parents born between 1954 and 1983. A multinomial logistic regression model is used to assess the relationship between parental separation and adherence to the vaccination schedule, accounting for the child's age at the time of parental break-up. Our results show that children who experience parental separation are less likely to receive all recommended vaccinations and are more likely to receive only mandatory vaccines or none at all. The negative effect is particularly pronounced for children who were younger at the time of separation. Given the rising incidence of family disruptions, these findings have important policy implications for improving vaccination uptake.

Keywords: parental separation, pediatric vaccination, Italy

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Introduction

The possible implications of family disruptions for children's outcomes have sparked increasing debate, particularly in the ongoing rise in family instability since the mid-20th century in Europe (Wagner, 2020). These trends are associated with the broader framework of the Second Demographic Transition (SDT), which encompasses shifts such as the rise in cohabitation, out-of-wedlock births, and higher rates of union dissolution, driven by changes in societal values like secularisation and the rise of post-materialist ideals (Lesthaeghe, 2020). A growing body of research highlights that children who experience parental break-up and are raised in single-parent households undergo negative outcomes across various aspects of life, including subjective well-being, behavioural issues, and education (Chapple, 2009; Amato, 2010; Härkönen et al., 2017).

A parallel trend in high-income countries is the growing hesitancy of parents towards important child vaccinations. An increasing number of parents hesitate to vaccinate their children due to worries about vaccine safety, even in the face of assurances from healthcare professionals and public health organizations (Kennedy, 2020). Incomplete vaccination among the pediatric population has been recognized as an increasing public health issue in high-income countries, with its determinants not fully understood (Jacques et al., 2022). Empirical studies have pointed out the role of the internet and social media in amplifying fears surrounding vaccines, as well as broader social and political factors such as declining trust in scientific and political institutions. However, very little is known about whether and how family disruptions may impact parental adherence to their children's vaccination schedules.

This study fills this gap in the literature by bringing together two research streams: the sociological and demographic study on the consequences of increasing family instability and parental separation for children's outcomes, and health research on children's vaccination coverage. It does so by examining the association between the experience of parental break-ups and children's pediatric vaccination in Italy. Based on unique data on Italian parents born between 1954 and 1983, a multinomial logistic regression model is used to assess the relationship between parental separation and adherence to vaccination schedules, accounting for the child's age at the time of parental break-up. The international literature provides very limited evidence on the association between parental separation and children's vaccination coverage, and in most studies, family characteristics are included only as control variables in the analysis.

Italy represents an interesting case study as a country experiencing a rapid diffusion of SDT-related family behaviours (Aassve et al., 2024). In recent years, vaccination uptake in Italy has declined, leading to a resurgence of infectious diseases. Between February 2017 and January 2018,

Italy accounted for 34% of all measles cases reported in the European Union (Siani, 2019). This alarming trend prompted the national government to introduce mandatory school-entry vaccinations. Previous studies in Italy reported varying levels of vaccine hesitancy, from 16% (Giambi et al., 2018) to approximately 35% (Napolitano et al., 2018). However, following the introduction of the Decree-Law 73/2017, which mandated vaccination by law, Italy achieved higher vaccination coverage than European countries relying solely on recommendations (Farina et al., 2014). Investigating whether family disruptions are associated with lower children's vaccination coverage is particularly important for public policy. The substantial rise in divorce rates and the resulting increase in the proportion of children living in single-parent households highlights a critical factor for effectively managing future vaccination coverage.

The paper is structured as follows: the next section reviews the theoretical and empirical literature on parental separation, its impact on children, and the connection between parental separation and vaccine administration, particularly focusing on the Italian context. Then, we explain our analytical approach and present the data, variables, and methodology. The results section includes both descriptive analyses and multivariable findings. Finally, the paper concludes with a discussion of the main findings.

Theoretical background

Parental separation and its consequences for children's outcomes

Starting from the late '60s, family structures have become increasingly varied across Western countries, and the conventional family model–characterised by a household consisting of a married couple and its children–has been replaced by a spectrum of different family configurations (Vignoli et al., 2014). The transformations of Western family structures mainly depend on a notable rise in marital breakdowns (Aassve et al., 2006). The rise in marital instability has led to an increase in second marriages and families with individuals who have prior marital experience, as well as single-parent households–predominantly single mothers. In the context of the broader Second Demographic Transition (SDT), which includes cohabitation replacing marriage and out-of-wedlock childbearing, an increasing number of children are experiencing the dissolution of (non-marital) parental unions (Lesthaeghe 2020).

Although the existing literature attests to the importance of the specific traits of the partners involved (Amato & Anthony, 2014), a substantial body of empirical research indicates that parental separation is linked to adverse outcomes for children across multiple areas (Amato, 2010; Härkönen et al., 2017). These detrimental effects extend to both short-term outcomes, such as academic

performance during high school (Amato & Anthony, 2014), increased stress and behavioural issues (Chapple, 2009), and long-term outcomes such as the likelihood of completing higher education (Bernardi & Radl, 2014; Guetto et al., 2022), potentially resulting in a cumulative disadvantage over the life course.

There are several mechanisms potentially linking the experience of parental separation to worse children's outcomes. Some of these mechanisms concern the process leading to (and preceding) parents' physical separation, such as increased family conflict and reduced parenting quality (Härkönen et al., 2017). The actual event of parental break-up brings a significant emotional burden and includes multiple practical aspects (such as changing residence, defining new financial/economic arrangements, dividing expenses, etc.) that further contribute to the already elevated stress levels (Amato, 1993, 2000; Johnson & Wu, 2002; Leopold & Kalmijin, 2021).

The new family arrangements following parental separation also affect the economic and social resources available to the child. Union dissolution and the transition to single parenthood often result in significant income and wealth losses, particularly for women (Andreß & Hummelsheim, 2009; Uunk, 2004). Women face additional challenges in balancing work and family responsibilities, as they typically assume the primary physical custody of the children (Boertien & Lersch, 2021; Aassve et al., 2007). Parental separation also influences the set of relational resources and the network of individuals (such as grandparents, family friends, common acquaintances, neighbours, etc.) the couple and children could rely on until before the parental break-up. In particular, it is common for children to lose regular contact with the non-custodial parent, usually the father (Amato 2010; Zilincikova & Albertini 2022; Tosi & Guetto 2024). As a result, children may have fewer opportunities to interact with grandparents and other relatives from the non-custodial side. This loss of contact can diminish the broader support network that the extended family typically provides, affecting the child's emotional and social development.

Children's Vaccination Coverage: Does Parental Separation Make a Difference?

Achieving and sustaining elevated vaccination coverage levels represents an essential public health strategy. Specifically, the World Health Organization (WHO) has advised achieving a minimum coverage of 95% to attain herd immunity for all vaccine-preventable infections. Nowadays, the remarkable achievements of immunisation programs in developed nations, characterised by decades of high vaccine adoption leading to herd immunity, are facing a challenge. The decline in perceived risks associated with vaccine-preventable infectious diseases has contributed to the widespread resistance or reluctance towards vaccination (Ajovalasit et al., 2021). This phenomenon, now recognised as "vaccine hesitancy" (MacDonald, 2015), is acknowledged as a major threat to global

health (WHO, 2019). The COVID-19 pandemic has further exacerbated the spread of misinformation (Skafle et al., 2022), intensifying the issue and making vaccine hesitancy even more relevant. It has also demonstrated that pandemics are not just historical events, but ongoing threats, underscoring the importance of maintaining public trust in vaccines to safeguard global health.

The bulk of research on vaccine hesitancy has focused on contextual, individual, and group-level factors that influence trust in the safety and effectiveness of vaccines, such as (social) media, political orientations, or issues specific to the design and delivery of vaccination programs (MacDonald, 2015). Among family characteristics, parental socioeconomic status has received much attention in the literature. It is well-known that higher education is linked to better access to health information and, thus, to better health-related decisions (Dominici and Dahlström, 2023). In particular, higher parental education is associated with better parental attitudes toward immunisation and higher children's vaccination coverage (Cantuária-Tauil et al., 2016; Brown et al., 2010; Danis et al., 2010). Other factors considered include parental age (Haynes et al., 2004), vaccination history of parents and siblings (Vandemerulen et al., 2008), and family and household composition (Danis et al., 2010; Vandemerulen et al., 2008).

Only a few studies have examined the association between parental separation and children's vaccination schedules, often considering family arrangements as a control variable rather than the main focus of the research. These studies suggest that children of single or divorced parents have lower vaccine coverage and higher non-compliance with vaccination schedules (Vandermeulen et al., 2007; Kacenelenbogen et al., 2014).

Although parental vaccine hesitancy is recognised in the literature as one of the most important predictors of children's vaccination coverage, we consider it unlikely to mediate the possible negative impact of parental union dissolution. There are few theoretical reasons to believe that experiencing union dissolution should directly make parents more hesitant toward their children's vaccinations, net of their socioeconomic characteristics. Instead, parents who separate may be systematically different from those who do not in ways that also relate to vaccine hesitancy. For instance, lower levels of conscientiousness (Arpino et al., 2022) may both increase the likelihood of separation and correlate with greater skepticism toward vaccines. More broadly, separated parents may be selected for unobserved characteristics such as lower trust in science or a preexisting reluctance to vaccinate. Thus, rather than reflecting a causal effect, any observed association between union dissolution and vaccine hesitancy may be better explained by these confounding factors.

A genuine negative impact of parental separation on children's vaccination coverage may stem from the psychological, social, and economic consequences of separation. While financial constraints may be less relevant in contexts where pediatric vaccinations are publicly funded, the psychological

strain and social disruptions following separation may play a more significant role. For instance, heightened stress and impaired communication between separated parents can reduce adherence to vaccination schedules. The post-separation period often involves major life changes, such as relocation or school transitions, creating additional stress and logistical challenges. These disruptions—combined with increased time constraints and a decline in shared parental decision-making—may hinder parents' ability to keep track of vaccination appointments.

Furthermore, reduced interaction with the non-custodial parent may weaken parental guidance and oversight, potentially increasing children's vulnerability to health risks (Hoffmann, 2017). Separated or divorced parents, particularly those not living with their children, tend to be less involved in their daily lives (Tosi & Guetto, 2024), which may affect their engagement with healthcare services, including vaccinations (Mackay, 2005). Additionally, single parents often have fewer social resources, such as support from extended family, friends, or neighbours, making it harder to navigate routine healthcare responsibilities. As a result, households headed by separated or single parents may face distinct challenges that affect their ability to manage their children's vaccination schedules effectively.

The Italian setting

Increasing separations and single-parent households

Despite the legalisation of divorce in 1970, marriage continued to hold a central role in Italian society well into the late 1990s. Eurostat data from 2000 reveals that Italy had a divorce rate of just 15 per 100 marriages, considerably below the EU-27 average of 36. Moreover, less than 10% of births occurred outside marriage, compared to about 25% in other European countries. However, by 2022, Italy's divorce rate had increased to 44 per 100 marriages, aligning with the rates observed in the Nordic countries, which had led the way in embracing new family dynamics. Simultaneously, the proportion of births outside marriage rose to 40%, nearly converging with the European average of 42%. Even though children still represent a significant "protective" factor against the risk of marital breakdown, their presence has become less influential compared to the past (Tocchioni & Meli, 2021). In 2021, 51% of legal separations and 38% of divorces involved the custody of children.

As a result of these changing family dynamics, an increasing number of Italian children spend part of their childhood and adolescence with only one co-resident parent–in about 80% of cases the mother, although the number of single-father households has been rising in recent years–or are raised by a single parent from birth. Eurostat data indicates that, in 2004, 11% of Italian adolescents aged

15 to 17 still living with their family were residing without one of their biological parents, a figure that increased to 17% by 2021.

The increase in family instability has been accompanied by a change in its socio-economic gradient (Goode, 1993). When legal, social, and economic obstacles to divorce were substantial, only highly educated individuals possessed the cultural and financial means to overcome them. However, as these barriers decreased, divorce became more attainable for couples with fewer resources, leading to its wider acceptance across different socioeconomic groups (Bastianelli et al., 2024).

Vaccination setting

The Italian vaccination setting has undergone numerous changes since the first vaccine was introduced for Diphtheria in 1939. Nowadays, the national administration is regulated according to an official plan released every two years called the National Immunization Plan (NIP). The first NIP was implemented in 1999 to achieve 95% coverage for poliomyelitis, tetanus, diphtheria, pertussis, measles, rubella, and parotitis by 2000, in line with the WHO's objective. Since its introduction, the vaccination programme has been updated several times, incorporating new vaccines and altering the requirements for mandatory and recommended immunisations.

Before 1999, the number of existing and mandatory vaccines varied over time and among regions, and no official plan regulated the administration of scheduled vaccinations (see Table A1 in the Appendix for more details on compulsory and non-compulsory vaccinations in the different vaccination periods). Earlier than 1991, when the Hepatitis B vaccine was made mandatory by law, the number of compulsory vaccinations was set to three (Diphtheria, Tetanus, and Poliomyelitis), with different eligibility ages. Since 1991 and up to 2017, four vaccinations have been made compulsory for children, including diphtheria, tetanus, poliomyelitis, and hepatitis B (Italian Ministry of Health, 2017a, b). According to the National Immunization Program (NIP) introduced in 1999, the initial vaccination is scheduled for newborns at 3 months of age. Most vaccines' first doses are administered within the first 15 months of life, while the second dose if required, is typically given by the time the child reaches 6 years of age. Decree-Law 73/2017 expanded the compulsory vaccination requirements for minors up to 16 years old from four to ten, adding to the previous four the following six vaccinations: pertussis, Haemophilus influenza, measles, mumps, rubella, and chickenpox. As per the law, individuals refusing vaccination may face fines, and children could be denied access to preschool services until 6 years old.

To sum up, nowadays, during the first 6 years of life, children in Italy receive approximately 16 vaccine doses, excluding the annual flu shot, which brings the total to 22 doses. Several vaccines are combined in a single shot (like the trivalent vaccine that protects against Diphtheria, Tetanus,

Pertussis, or the Hexavalent, which adds to the previous three diseases also the protection against Poliomyelitis, Hepatitis B, and Haemophilus influenza), thus simplifying the immunization process. The national system requires active involvement from parents, who must arrange appointments with their local health authority (ASL) or their child's pediatrician. Finally, a limited number of vaccinations (boosters and new vaccines) are administered at older ages, during pre-adolescence and adolescence. For instance, when the HPV vaccine was introduced, it was proposed for 11-year-old girls in 3 doses; then, recently, the target age was lowered to about 9 years for both girls and boys in two doses (Italian Ministry of Health, 2024).

The Decree-Law 73/2017 was introduced as a response to the decrease in the coverage of MMR (measles, mumps, and rubella), which fell to 85% in 2015 and remained low after that, in the context of increasing debate on vaccination mandates[1]. The immediate effect of the Italian legislation was a rise in vaccination rates for the hexavalent and MMR vaccines, which reached approximately 95% coverage in 2019 (D'Ancona et al., 2019). In the following years, vaccination rates in Italy further decreased, largely due to the impact of the COVID-19 pandemic. By 2022, however, a general improvement was observed in coverage for most recommended early childhood vaccinations (at 24 and 36 months) compared to the previous year. Notably, polio coverage (used as a proxy for the hexavalent vaccine) and measles coverage in the 2020 cohort reached 95% and 94%, respectively. Despite these improvements, booster shot coverage at ages 5–6 and during adolescence remains below the desired target levels (Italian Ministry of Health, 2022).

Since their introduction, vaccines in Italy have been actively provided free of charge to individuals belonging to specific age groups (for example, children and older adults) or risk categories (pregnant women) through public immunisation services (Pezzotti et al., 2018; D'Ancona et al., 2019). This ensures that financial barriers to children's vaccinations do not represent a risk factor for refusal or delay. An important structural determinant of adherence to vaccination schedules is the decentralisation of the Italian healthcare system. This decentralisation results in significant variations in health services across different regions (Fiasca et al., 2019; Cicchetti & Gasbarrini, 2016). Disparities in policies and funding at the regional level contribute to substantial vertical fragmentation in the scope and quality of health strategies. Notably, regions or local health authorities in the northern part of the country are often considered centres of excellence, while the rest of the nation experiences varying standards (Cicchetti & Gasbarrini, 2016). These regional disparities can impact the diverse levels of adherence to vaccine supply in different areas of the country.

[1] A survey undertaken in 2016 involving over 3000 Italian parents revealed that while only 0.7% identified as "anti-vaccine", 16% expressed hesitancy (Giambi et al., 2018).

Research hypotheses

This study explores the association between parental separation and pediatric vaccination compliance in Italy, a country experiencing rapid demographic changes. While there is a bulk of research on the diffusion of new family behaviours and their determinants, the existing research does not adequately explore how parental separation may impact health behaviours, especially regarding children's vaccination adherence.

Separated or single-parent families often face greater challenges than two-parent families, including heightened stress and reduced social networks. These factors can lead to less time spent with children and decreased involvement in childcare, especially from the non-custodial parent. As a result, separated parents may be more likely to miss or forget vaccination appointments. Our first hypothesis thus posits that *separated parents are more likely to fail to administer all available pediatric vaccinations or to provide only the compulsory ones* (H1). In addition, we also seek to explore how the timing of parental separation influences vaccination adherence. In particular, we predict that *separations occurring during the first two years of a child's life should have the most significant effect on adherence to vaccination schedules* (H2). Nevertheless, some negative effects of parental separation on pediatric vaccination may persist beyond the first few years of a child's life, as the years preceding parental separation are often characterised by significant familial turbulence (Amato, 2000).

Italian legislation on pediatric vaccination has evolved over time, with stricter requirements introduced following the NIP in 1999 and further reinforced in 2017 by the Decree-Law 73/2017. By reducing parental discretion over vaccine administration, these institutional changes may have mitigated the potential negative consequences of parental separation, especially for the younger cohorts. However, while the number of mandatory vaccines has increased, many important vaccines remain non-mandatory despite being strongly recommended by the Italian Ministry of Health (see Table A1 in the appendix). This divergence may have widened the disparity between cohabiting parents–who are better equipped to navigate the growing vaccination requirements–and separated parents, who may struggle to meet all healthcare obligations for their children. Although the introduction of combined vaccines (e.g., trivalent and hexavalent) has simplified the process by administering multiple doses at once, the overall management of vaccination schedules has become more complex, potentially exacerbating challenges for separated parents. Moreover, while penalties such as fines or denied school access exist in principle, they are often not strictly enforced, which may further contribute to disparities in vaccination coverage.

As a result, it remains difficult to determine whether and how the impact of parental separation has changed over time, despite the increasing institutionalization of pediatric vaccinations. Given

these competing mechanisms, we hypothesize that *the negative effect of parental separation on children's vaccination coverage persists regardless of the time period (H3)*.

Data & Methods

To analyse the relationship between family dynamics and children's vaccination outcomes, we relied on data from an online survey conducted by the Italian branch of Bilendi, a multinational market research company leader in the academic sector, and specialized in the creation of panels to investigate social aspects of public health issues[2]. The survey was administered between September 15th and October 10th 2023, to 12,004 individuals above 40 residing in Italy and recruited through online panels. Due to the nature of our study, participants were self-selected for the panel and subsequently chose whether to engage in the survey, which means our sample does not adhere to traditional probabilistic sampling methods. To address this limitation, we implemented national quotas to align our data with the population distribution across various sociodemographic characteristics, including gender, age, marital status, education level, employment status, and geographic region. This quota-based approach helped ensure that our final sample closely reflected national demographics outlined by the Italian National Institute of Statistics. We also applied post-stratification weights to correct minor discrepancies from the benchmark population data. The original sample was restricted to 6,517 respondents who declared to be parents at the interview date and were born between 1954 and 1983.

The *dependent variable* measured the youngest child's vaccination status as reported by the respondents, identifying the set of vaccines administered/not administered into three categories, i.e. no vaccines, only mandatory vaccines, and all vaccines recommended at that time by the Italian Ministry of Health. The *key independent variable* identifies whether the respondent has ever experienced the end of a co-residence relationship, including both marital and non-marital unions, distinguished by the age of the youngest child at the moment of a parental break-up, i.e., the moment in which the parents physically separated. We could not distinguish whether family disruption occurred due to parental union dissolution or the partner's death. However, given that the analysis concerns family disruptions during the youngest child's childhood and adolescence, parental deaths are likely to represent a minority of cases, especially in the youngest age group. The four-category variable is as follows: (1) went through a separation before the youngest child turned three; (2) experienced it between the third and the eighth year of the youngest child's life; (3) experienced it

[2] More information on academic projects based on Bilendi data is available at the following website: https://www.bilendi.it/academics

between the ninth and eighteenth year of the youngest child's life; (4) never separated[3]. This categorisation accounts for important deadlines in vaccine administrations since the introduction of the first vaccine in 1939. After the release of the first NIP in 1999, most pediatric vaccines are supposed to be administered from 3 months to 13-15 months of the child's birth, with other boosters being required when children are between five and six years old. Nevertheless, a few vaccines are also administered during pre-adolescence and adolescence (e.g., the HPV vaccine). In addition, parental conflict often intensifies, and the family environment deteriorates well before the separation (Härkönen et al., 2017). Consequently, adverse effects on a child's vaccination status might arise even if the physical separation occurs after the youngest child has turned nine.

As for the methodology, we used a multinomial logistic model (M1) to examine the impact of the timing of parental separation on the child's vaccination outcome, net of control variables, to assess our hypotheses H1 and H2. Control variables include several respondent's characteristics, such as birth cohort (1954-1963, 1964-1973, 1974-1983), number of children (1, 2, 3 or more), sex (male, female), and the area of residence (North, Centre, and South). The latter accounts for the decentralisation of the Italian healthcare system and the subsequent variations in health services across different regions (e.g., Fiasca et al., 2019). Also, we included his/her educational level, classified into four categories: (1) up to lower secondary, (2) upper secondary, (3) tertiary in health-related fields, or (4) tertiary in other fields of study. While the link between the level of education and vaccination attitudes is well established in the literature, a healthcare-related qualification may play an even more significant role in shaping these attitudes. Finally, we included information on the pediatric vaccinations received by respondents (All vaccines, Only Compulsory, None), which reflects their childhood experience with vaccinations and may have influenced their attitudes toward vaccinating their children. However, since this data was collected through a retrospective question, recall bias could affect the accuracy of the information provided.

Model M1 is then augmented in two ways. First, in model M2, we assessed whether the effect of parental separation on children's vaccination outcomes persists even when accounting for distrust in science and vaccine misbeliefs, measured by 5 and 4 items, respectively, with a 5-point Likert scale ranging from "completely disagree" (1) to "completely agree" (5)[4]. Two indexes were created for each dimension, including respondents who answered at least two items, by summing the responses

[3] We excluded from the analysis 271 children whose parents separated after they had turned 18 years old.

[4] As for science distrust, the asked items are: 1) *scientists ignore results that contradict their work*; 2) *scientists do not consider others' ideas*; 3) *scientists' work contributes to improving people's lives*; 4) *most scientists conduct their work honestly*; 5) *science cannot be trusted because it progresses too slowly*. For vaccine misbeliefs, the four items are: 1) *vaccines work on the immune system*; 2) *vaccines often cause severe and irreversible side effects*; 3) *vaccines do not protect against diseases; instead, they cause them in severe forms*; 4) *the pharmaceutical industry administers harmful treatments (e.g., vaccines) without people's consent to make them ill and increase the sales of medications (produced by them)*.

and normalising the total on a 0-10 scale so that higher index values correspond to higher distrust / misbelief. The original indexes were then categorised into 3 main categories, indicating low (0-3), medium (4-6) and high (7-10) levels of scientific distrust and misbelief. It is important to note that these attitudes were measured at the time of the interview. However, existing evidence suggests that such attitudes remain relatively stable over the life cycle (Duradoni et al., 2024), making it reasonable to assume that they reflect the attitudes held at the time of children's vaccinations. Second, we extended model M1 by incorporating an interaction between respondents' birth cohort (1954-1963, 1964-1973, 1974-1983) and the youngest child's age at parental separation to test for hypothesis H3 (model M3).

To enhance the interpretability of the findings, results are presented in terms of average marginal effects, i.e. differences in predicted probabilities for the youngest child of being vaccinated with all vaccines, only compulsory vaccines, or none, according to whether and when the child experienced parental separation. The reference group was defined as the category of individuals who "never separated," with vaccination outcomes for children compared to those in other categories.

Results

Descriptives

Overall, 4.2% of respondents experienced union dissolution when their youngest child was 2 years old or younger, 7.3% when their youngest child was between 3 and 8 years old, and 9.1% when their youngest child was between 9 and 18 years old. In contrast, 79.3% of respondents did not separate (see Table A2 in the Appendix). Regarding children's vaccination status (see Table 1 below), approximately 5% of respondents chose not to vaccinate their child, 45% exclusively adhered to compulsory vaccinations, and around 50% ensured their children received all vaccinations indicated as compulsory or recommended by the then Ministry of Health program. Despite, children who underwent parental separation during childhood or adolescence received fewer vaccinations compared to those who did not experience parental separation. Specifically, 9% of children who experienced parental separation before 3 years of age did not receive any vaccines, compared to 4% of those whose parents never separated. The risk of being completely unvaccinated decreases to 8% for children who experienced parental separation between 3 and 8 years, and to 4% for those who were between 9 and 18 years old. Looking at completing the vaccination schedule, there is a difference of 12 percentage points (pp) between parents who never separated (52%) and those who separated in the first three years of the youngest child's life (40%). The gap between separated and

non-separated parents decreases to around 7-8 pp when considering family disruptions occurring at children's older ages.

Table 1: Respondents' experience of separation at different ages of their youngest child and the corresponding number of vaccinations their child received—weighted absolute and column percentage frequencies.

	Experience and timing of separation				**Total**
Vaccines received	Not separated	Separated within 2 years	Separated within 3 to 8 years	Separated within 9 to 18 years	
	N *(%)*	N *(%)*	N *(%)*	N *(%)*	**N *(%)***
All vaccines	2,585 (*52*)	106 (*40*)	203 (*45*)	250 (*44*)	**3,143 (*50*)**
Only compulsory	2,158 (*44*)	135 (*51*)	216 (*48*)	295 (*52*)	**2,805 (*45*)**
None	213 (*4*)	23 (*9*)	36 (*8*)	26 (*4*)	**298 (*5*)**
Total	**4,956 *(100)***	**264 (*100*)**	**455 (*100*)**	**571 (*100*)**	**6,246 (*100*)**

Multinomial logistic regression on parental separation and children's vaccination coverage

Figure 1 presents the average marginal effects (AMEs) derived from two multinomial logistic regression models, with (M2) and without (M1) the inclusion of the two indicators of science distrust and vaccine misbeliefs, respectively. The AMEs illustrate differences in the probability of receiving all vaccines, only the compulsory ones, or none, between children who experienced parental separation at different ages before turning 18, with respect to those who did not.

Model M1 shows that children who experienced parental separation have a significantly lower probability of receiving all recommended vaccines than those in non-separated households. Specifically, for children who experienced parental separation within the first three years of life, the probability of receiving all vaccines is 14.9 pp lower compared to those whose parents never separated. For children aged 3 to 8 years and 9 to 18 years at the time of separation, the probabilities are lower by 7.2 and 8.9 pp, respectively, compared to the reference group (see Table A4 in the appendix for full model results).

The situation is reversed when analysing the other two outcomes, "Only Compulsory" and "None". Children from separated families are more likely to have only received the compulsory vaccines compared to those from non-separated families. In particular, for children who experienced parental separation before the age of three, the probability is 11.6 pp higher. For children in older age groups at the breakup, the probability increases by 4.7 pp and 8.6 pp, respectively.

Regarding the last outcome, i.e. the youngest child received no vaccines at all, the results are consistent with the previous findings. The probability of not receiving any vaccines is 3.4 pp higher for children who experienced parental break-up within the first three years of life, and 2.5 pp higher

for those from families disrupted when they were between 3 and 8 years old. No significant differences are observed for children who experienced a breakup between the 9th and 18th birthdays compared to those from non-separated families.

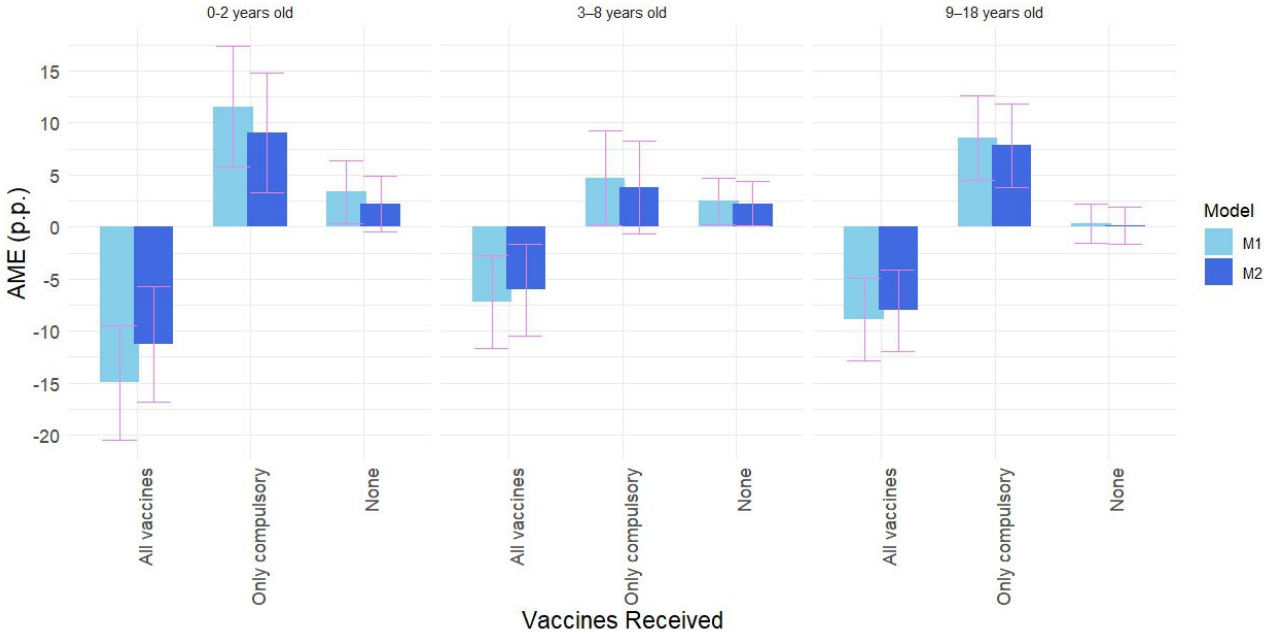
To sum up, results are consistent with our hypothesis H1, showing that separated parents are more likely to fail to administer all available pediatric vaccinations. Instead, our hypothesis H2 is only partly confirmed because the trend is not linear with children's age at separation: while children experiencing parental separation at a very early age (below 3 years of age) are the most affected, no substantial differences emerged when parental separation occurred when the youngest child was aged 3-8 or 9-18.

Results of model M2, which includes science distrust and vaccine misbeliefs (darker bars in Figure 1), are largely consistent with those of model M1, thus showing that vaccine hesitancy does drive the effect of parental separation. Overall, the magnitude of the negative effects of parental separation is weaker, though. In line with the literature, science distrust and vaccine misbeliefs are strongly associated with children's vaccination coverage (see Table A4 in the appendix for full model results). For instance, children whose parents rank high in vaccine misbeliefs and science distrust have, respectively, a 21.6 pp and 16.5 pp lower probability of having received all vaccines, compared to their peers with parents who score low in misbeliefs and distrust. Given that separated respondents score higher on such attitudes (Table A3 in the appendix), their inclusion in the model slightly reduces the impact of parental separation. In particular, the AME of parental separations occurring within two years of age of the child on his/her probability of receiving all vaccines shifts from -14.9 to -11.3 pp, while the corresponding AMEs for the 'only compulsory' outcome shifts from 11.6 to 9.1 pp. In all other cases, the coefficients in model M2 are similar to the reduced model M1, and their differences are not statistically significant[5].

The results obtained for the control variables align with previous findings (see Table A4 in the appendix). For instance, the likelihood of children receiving all vaccines significantly increases when respondents have attained tertiary education, particularly for those who obtained a health-related degree, showing a 15.1 pp higher probability for model M1 compared to those with an upper secondary education. We tested for potential heterogeneity in the effect of parental separation by parental education. The results (available upon request) show no statistically significant interactions, indicating that the effect of parental separation on children's vaccination does not vary based on parental education.

[5] We used the Karlson–Holm–Breen (KHB) method (2012) to test the statistical significance of the differences between the regression coefficients for parental separation in Model M1 and M2, and found that only the coefficients associated with parental separation during the child's first three years of life differed significantly.

Figure 1: Multinomial regression model results for the probability that the youngest child was vaccinated with "All vaccines", "Only compulsory", or "None" by the time of separation (reference category: "Never separated"). AME with 95% confidence intervals for model M1 and model M2 (augmented with science distrust and vaccine misbeliefs).

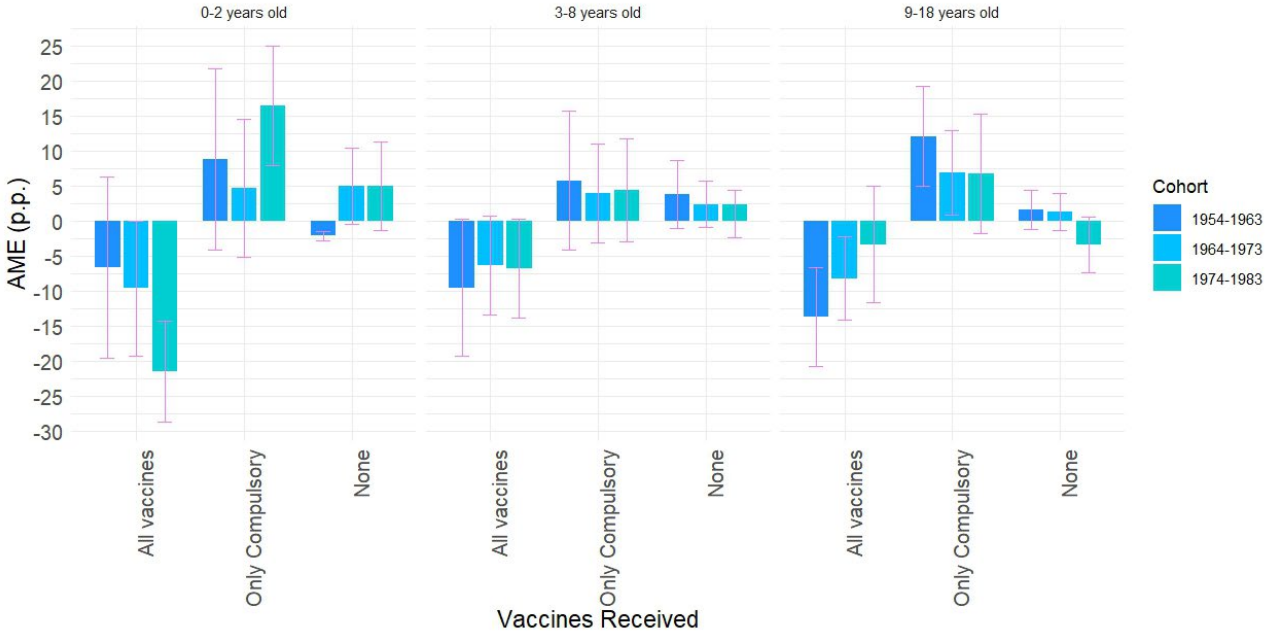


Results in Figure 2 (model M3) show that the impact of the timing of parental separation on vaccination outcomes varies by vaccines received and respondents' birth cohort (see Table A5 for full model results). The negative (positive) effects of an early separation (0-2 years) on children's probabilities of receiving all (only compulsory) vaccines are more pronounced among the youngest cohorts of respondents born between 1974 and 1983, with AMEs of -21.5 pp and +16.6 pp, respectively. This result suggests that the more intensive vaccination schedule introduced by the National Immunization Plan, along with its recent reforms—particularly in the first three years of life—has amplified the challenges posed by parental separation. In contrast, older cohorts followed a less stringent vaccination schedule for children aged 0 to 2, which may have made it easier for parents to adhere to vaccination protocols, even in cases of parental separation during the child's early years.

However, the effects of parental separations occurring when the youngest child is aged 9 or older are more pronounced among the older cohorts. Specifically, the 1954–1963 and 1964–1973 cohorts showed statistically and substantially significant negative impacts on the "All vaccines" outcome (–13.8 pp and –8.2 pp, respectively) and significant positive impacts on the "Only compulsory" outcome (12.1 pp and 6.9 pp, respectively). These results may reflect the different vaccination schedules these parents encountered before the introduction of the first National Immunization Program. Prior to 1999, the overall number of vaccines (both compulsory and voluntary) was relatively low, and the administration periods were less clearly defined and more extended. As a result, catch-up vaccination campaigns were implemented as new vaccines (such as

HPV or Hepatitis) were introduced, often when these parents' children were older. This extended the potential negative consequences of parental separation over a longer period of the child's life.

Figure 2: Multinomial regression model results for the probability that the youngest child was vaccinated with "All vaccines", "Compulsory", or "None" by the time of separation (reference category: "Never separated") and parents' birth cohort. AME with 95% confidence intervals for model M3.



Conclusions

Parental separation and growing up with only one of the biological (or adoptive) parents for a significant period during childhood and adolescence can have negative effects on children's emotional, cognitive, and behavioural development. However, very few studies have examined the role played by parental separation in children's vaccination coverage. In this paper, we fill this gap in the literature by focusing on the case of Italy, a country that experienced a substantial increase in the number of children undergoing parental separation and living in single-parent households starting in the early 2000s. We tested whether children of separated parents were less likely than their counterparts who never experienced parental separation before turning 18 to receive all the recommended pediatric vaccinations, and more likely to only receive the compulsory ones or to receive no vaccination at all (hypothesis H1). In addition, we also explored how the timing of parental separation influences children's vaccination adherence. We predicted that separations occurring during the first three years of a child's life should have the most significant effect on children's

vaccination coverage (hypothesis H2), given that most vaccinations are administered in that time frame.

Our analysis revealed that children of separated parents are less likely to receive all recommended vaccines compared to children from non-separated parents. The vaccination coverage gap was more pronounced for parents who separated when the youngest child was between 0 and 2, with a 14.9 percentage point lower probability of receiving all vaccines. Although the differences in vaccination likelihood decrease for children who were older at the time of parental separation (between 3 and 8 or between 9 and 18 years), they remain substantially and statistically significant. This result can be understood by conceptualizing parental separation as a process that often begins years before and extends well beyond the actual break-up (Härkönen et al., 2017), affecting children through increased parental conflict and stress within the family. For this reason, parental separation could have had an impact on adherence to vaccination schedules even before the date of the physical parental separation. Children from separated families have a higher probability of receiving only compulsory vaccines, and those who were under the age of nine at the time of separation are even more likely not to have received any vaccinations.

Due to data limitations, we were not able to disentangle the mechanisms through which parental separation negatively impacts children's vaccination. However, we tested empirically whether and to what extent the effect of parental separation could be accounted for by distrust in science and vaccine-related misbeliefs, well known in the literature as the most important predictors of children's vaccination coverage. After including these variables in the model, we found a statistically significant increase in the probability of receiving all vaccines among children who experienced parental separation in the first three years of life, and a corresponding decrease in their risks of receiving only the compulsory vaccines or no vaccines at all. All other separation penalties remained unchanged. Overall, the inclusion of these attitudinal factors did not substantially alter the relationship between parental separation and children's vaccination outcomes. This finding suggests that science distrust and vaccine misbeliefs, while strongly predicting parental adherence to their children's vaccination schedules, are unlikely to mediate the effects of parental separation, nor are separated parents systematically selected for negative attitudes toward science and vaccines. The mechanisms underlying the effect of separation are more likely related to its psychological and social consequences for the parents involved.

Also, we explored the role of parental separation for children's vaccination over time through the respondents' birth cohort. We discussed how the effect of stricter regulation of pediatric vaccinations, through the National Immunization Plans (NIP) starting in 1999, on the separation penalty is ambiguous. The higher availability of compulsory vaccines reduces the role of parental

decision-making; however, the availability of an increasing number of recommended, non-compulsory vaccines, while making the vaccination schedule more demanding, acts in the opposite direction of increasing the role of parental decision-making. Results show that the overall negative effect of parental separation on children's vaccination coverage persists across all parental cohorts considered, regardless of the recent institutionalization of pediatric vaccinations through the NIP. In fact, this effect appears to strengthen over time for separations that occur at very young ages. However, while the negative impact of parental separation is concentrated in the early years of life for the youngest parental cohorts, for older cohorts, the effects are pronounced for separations at later ages, too. These variations are likely due to differences in vaccine availability and scheduling.

These findings highlight the importance of incorporating family dynamics into public health strategies aimed at improving children's vaccination coverage. Family dynamics are closely tied to social stratification: as union dissolutions increasingly occur among lower socioeconomic groups (for Italy, see Bastianelli et al., 2023), who already have lower vaccination coverage, diverging trajectories are likely to emerge. The vaccination outcomes of children from disadvantaged families will be more negatively impacted by growing family instability compared to those from more advantaged backgrounds. Policymakers should take into account the timing of parental separation in mitigating the risks of lower vaccination rates in vulnerable populations. Additionally, efforts to reduce vaccine misbeliefs and enhance public trust in science could play a critical role in improving vaccination outcomes across various family contexts.

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Appendix

Table A1 - Compulsory and non-compulsory vaccinations before the National Immunization Plan (1999), after the first introduction of the NIP, and after the introduction of Decree-Law 73/2017.

Calendar period	Compulsory vaccines	Non-compulsory vaccines
Before 1999	**Diphtheria** **Tetanus** **Poliomyelitis** (OPV) **Hepatitis B**	**Pertussis** **Haemophilus influenza** **Measles, Mumps, Rubella** (all available combined in the MMR)
1999-2016	**Diphtheria** **Tetanus** **Poliomyelitis** (OPV) **Hepatitis B**	**Pertussis** **Haemophilus influenza** **Measles, Mumps, Rubella, +** **Chickenpox** (all available combined in the MMR or the MMRC) **+ Rotavirus** **+ Meningococcus A, C, W135, Y** **+ Meningococcus B** **+ Pneumococcal Conjugate Vaccine** (PCV) **+ Human Papillomavirus** (HPV)
After 2016	**Diphtheria** **Tetanus** **Poliomyelitis (OPV)** **Hepatitis B** **+ Pertussis** **+ Haemophilus influenza** **+ Measles, Mumps, Rubella, Chickenpox** (all available combined in the MMR or the MMRC)	**Rotavirus** **Meningococcus A, C, W135, Y** **Meningococcus B** **Pneumococcal Conjugate Vaccine** (PCV) **Human Papillomavirus** (HPV)

Table A2– Distribution of main independent variable *Experience and timing of separation*. Weighted absolute and percentage frequencies.

Experience and timing of separation	N	%
Never separated	4,956	79.3
Within 2 years	264	4.2
Within 3 to 8 years	455	7.3
Within 9 to18 years	571	9.1
Total	**6,246**	**100.00**

Table A3 – Distribution of socio-demographic characteristics of the sample by parental separation. Weighted absolute and percentage frequencies.

Sample socio-demographic characteristics	Never separated		Separated		Total	
Sex	n	%	n	%	n	%
Female	2,539	51.23	641	49.69	3,180	50.91
Male	2,417	48.77	649	50.31	3,066	49.09
Birth cohort						
1954–1963	1,731	34.93	320	24.81	2,051	32.84
1964–1973	1,779	35.90	537	41.63	2,316	37.08
1974–1983	1,446	29.18	433	33.57	1,879	30.08
Education						
Up to lower secondary education	2,239	45.18	558	43.26	2,797	44.78
Upper secondary education	1,930	38.94	505	39.15	2,435	38.98
Health Degree	87	1.76	24	1.86	111	1.77
Non-Health Degree	700	14.12	203	15.74	903	14.46
Region of residence						
Northern Italy	2,273	45.86	637	49.38	2,910	46.6
Central Italy	929	18.74	298	23.10	1,226	19.63
Southern Italy & Islands	1,754	35.39	355	27.52	2,109	33.77
Number of Children						
1	1,803	36.38	598	46.36	2,401	38.44
2	2,520	50.85	563	43.64	3,083	49.36
3 or more	633	12.77	129	10.00	762	12.2
Own vaccines when young						
All vaccines	2,471	49.86	662	51.32	3,133	50.17
Only compulsory	2,277	45.94	572	44.34	2,849	45.61
Few or none	68	1.37	28	2.17	96	1.54
I do not remember	140	2.82	28	2.17	168	2.68
Vaccine misbeliefs (index)						
Low [0-3)	2,273	46.18	501	39.08	2,775	44.43
Medium [3-6]	2,464	50.06	711	55.46	3,175	50.83
High (6-10)	185	3.76	70	5.46	256	4.10
Missing	34	0.69	8	0.62	42	0.67
Distrust in science (index)						
Low [0-3)	2,311	47.05	542	42.34	2,853	45.68
Medium [3-6]	2,476	50.41	691	53.98	3,166	50.69
High (6-10)	125	2.54	47	3.67	173	2.77
Missing	44	0.90	10	0.78	54	0.86
Total	**4,956**	**100**	**1,290**	**100**	**6,246**	**100.00**

Table A4– Multinomial regression model results for the probabilities of the youngest child receiving "All vaccines", "Only Compulsory", or "None" by control variables. Model M1 and M2. AME, p-value and 95% CI.

Variable	Vaccines received	Model M1 (without misbeliefs and distrust)				Model M2 (with misbeliefs and distrust)			
Experience and timing of separation (Ref="Never separated")		AME (p.p)	P>|z|	95% C.I.		AME (p.p)	P>|z|	95% C.I.	
Within 2 years	All vaccines	-14.93	0.000	-20.43	-9.44	-11.28	0.000	-16.81	-5.75
	Only compulsory	11.57	0.000	5.80	17.34	9.06	0.002	3.33	14.78
	None	3.36	0.031	0.30	6.42	2.22	0.106	-0.47	4.91
Within 3 to 8 years	All vaccines	-7.16	0.000	-11.63	-2.70	-6.04	0.007	-10.44	-1.63
	Only compulsory	4.70	0.042	0.17	9.23	3.80	0.097	-0.69	8.28
	None	2.46	0.030	0.24	4.68	2.24	0.040	0.11	4.37
Within 9 to18 years	All vaccines	-8.89	0.000	-12.88	-4.89	-8.02	0.000	-11.94	-4.11
	Only compulsory	8.55	0.000	4.48	12.62	7.85	0.000	3.83	11.87
	None	0.34	0.720	-1.51	2.20	0.18	0.845	-1.61	1.96
Gender (Ref = "Female")									
Male	All vaccines	-10.38	0.000	-12.46	-7.85	-10.55	0.000	-12.81	-8.28
	Only compulsory	7.91	0.000	5.17	9.81	8.17	0.000	5.87	10.47
	None	2.47	0.000	1.61	3.71	2.37	0.000	1.33	3.42
Education (Ref= "Upper secondary education")									
Up to lower secondary education	All vaccines	-4.90	0.000	-7.44	-2.36	-2.32	0.071	-4.84	0.20
	Only compulsory	2.81	0.000	0.25	5.37	0.87	0.505	-1.69	3.42
	None	2.10	0.032	0.94	3.25	1.45	0.011	0.34	2.57
Health-Degree	All vaccines	15.14	0.000	6.51	23.77	10.26	0.025	1.28	19.23
	Only compulsory	-14.97	0.001	-23.44	-6.51	-11.25	0.014	-20.22	-2.27
	None	-0.17	0.925	-3.64	3.31	0.99	0.669	-3.55	5.52
Non-Health Degree	All vaccines	4.36	0.016	0.80	7.91	1.49	0.407	-2.03	5.01
	Only compulsory	-4.94	0.006	-8.49	-1.38	-2.76	0.130	-6.35	0.82
	None	0.58	0.437	-0.89	2.04	1.27	0.130	-0.37	2.92
Birth cohort (Ref.= "1974-1983")									
1954-1963	All vaccines	5.90	0.000	2.96	8.84	4.06	0.006	1.16	6.97

	Only compulsory	-0.4	0.977	-7.31	4.41	1.33	0.381	-1.65	4.31
	None	-5.86	0.000	-3.03	-2.95	-5.40	0.000	-6.83	-3.97
1964-1973	All vaccines	9.52	0.000	6.68	12.35	8.72	0.000	5.93	11.51
	Only compulsory	-5.02	0.001	-7.88	-2.15	-4.47	0.002	-7.32	-1.62
	None	-4.49	0.000	-5.99	-3.00	-4.25	0.000	-5.70	-2.81
Number of Children (Ref. = “1”)									
2	All vaccines	-1.19	0.353	-3.69	1.31	-0.69	0.583	-3.15	1.77
	Only compulsory	0.69	0.589	-1.82	3.21	0.38	0.765	-2.11	2.88
	None	0.49	0.375	-0.58	1.58	0.31	0.576	-0.77	1.39
3 or more	All vaccines	-4.14	0.034	-7.96	0.31	-3.77	0.049	-7.53	-0.01
	Only compulsory	1.90	0.377	-1.98	5.77	1.57	0.424	-2.28	5.42
	None	2.24	0.026	0.27	4.21	2.20	0.027	0.25	4.15
Own vaccines when young (Ref. = “None”)									
All vaccines	All vaccines	29.21	0.000	19.46	38.97	19.70	0.000	9.43	29.97
	Only compulsory	-17.28	0.001	-27.31	-7.19	-12.17	0.019	-22.31	-2.03
	None	-11.96	0.001	-18.65	-5.28	-7.53	0.006	-12.86	-2.20
Only compulsory	All vaccines	-5.47	0.273	-15.28	4.31	-12.36	0.018	-22.62	-2.09
	Only compulsory	15.89	0.002	5.79	25.98	19.10	0.000	8.94	29.25
	None	-10.42	0.002	-17.13	-3.71	-6.74	0.013	-12.07	-1.41
I do not remember	All vaccines	9.59	0.122	-2.56	21.74	5.74	0.368	-6.76	18.23
	Only compulsory	-4.27	0.499	-16.66	8.11	-2.48	0.694	-14.86	9.89
	None	-5.32	0.188	-13.24	2.50	-3.25	0.322	-9.70	3.19
Region of residence (Ref. = “Center”)									
Northern Italy	All vaccines	0.13	0.932	-3.23	2.97	0.48	0.760	-2.58	3.53
	Only compulsory	-0.28	0.859	-3.40	2.83	-0.60	0.706	-3.71	2.51
	None	0.42	0.573	-1.03	1.86	0.12	0.874	-1.38	1.63
Southern Italy & Islands	All vaccines	-2.44	0.145	-5.71	0.84	-0.17	0.916	-3.41	3.07
	Only compulsory	3.25	0.053	-0.04	6.55	1.71	0.307	-1.58	5.00
	None	-0.81	0.274	-2.23	0.64	-1.54	0.042	-3.02	-0.05
Vaccine misbeliefs (Ref=“Low”)									
Medium	All vaccines					-12.59	0.000	-15.35	-9.83
	Only compulsory					8.27	0.000	5.51	11.04

	None					4.32	0.000	3.17	5.46
High	All vaccines					-21.60	0.000	-28.21	-15.00
	Only compulsory					13.42	0.000	6.75	20.10
	None					8.18	0.000	4.38	11.98
Science distrust (Ref=“Low”)									
Medium	All vaccines					-9.17	0.000	-11.89	-6.46
	Only compulsory					9.50	0.000	6.76	12.25
	None					-0.33	0.614	-1.62	0.96
High	All vaccines					-16.48	0.000	-24.41	-8.55
	Only compulsory					12.61	0.002	4.60	20.62
	None					3.87	0.035	0.27	7.47

Table A5– Multinomial regression model results for the probabilities of the youngest child receiving "All vaccines", "Only Compulsory", or "None" by control variables and by interaction (Cohort*Experience and timing of Separation). Model M3. AME, p-value and 95% CIs.

Variable	Vaccines received	Model M3 (with interaction)			
		AME (p.p.)	P>|z|	95% C.I.	
Gender (Ref = "Female")					
Male	All vaccines	-10.22	0.000	-12.52	-7.91
	Only compulsory	7.57	0.000	5.25	9.89
	None	2.65	0.000	1.59	3.71
Education (Ref= "Upper secondary education")					
Up to lower secondary education	All vaccines	-5.05	0.000	-7.59	-2.50
	Only compulsory	2.89	0.027	0.33	5.46
	None	2.16	0.000	1.00	3.32
Health-Degree	All vaccines	15.06	0.001	6.46	23.66
	Only compulsory	-14.93	0.001	-23.38	-6.48
	None	-0.13	0.942	-3.61	3.35
Non-Health Degree	All vaccines	4.44	0.014	0.88	7.99
	Only compulsory	-5.01	0.006	-8.56	-1.46
	None	0.58	0.438	-0.88	2.04
Birth cohort (Ref.= "1974-1983")					
1954-1963	All vaccines	5.68	0.000	2.72	8.64
	Only compulsory	0.14	0.927	-2.87	3.14
	None	-5.82	0.000	-7.27	-4.36
1964-1973	All vaccines	9.25	0.000	6.40	12.09
	Only compulsory	-4.77	0.001	-7.65	-1.88
	None	-4.48	0.000	-5.97	-2.99
Number of Children (Ref. = "1")					
2	All vaccines	-1.15	0.370	-3.65	1.36
	Only compulsory	0.72	0.578	-1.80	3.23
	None	0.43	0.439	-0.66	1.52
3 or more	All vaccines	-3.97	0.042	-7.79	-0.14
	Only compulsory	1.80	0.363	-2.08	5.68
	None	2.16	0.031	0.20	4.13
Own vaccines when young (Ref. = "None")					
All vaccines	All vaccines	29.39	0.000	19.66	39.12
	Only compulsory	-17.42	0.001	-27.49	-7.35
	None	-11.97	0.000	-18.67	-5.27
Only compulsory	All vaccines	-5.23	0.293	-14.98	4.52
	Only compulsory	15.69	0.002	5.58	25.79
	None	-10.46	0.002	-17.18	-3.73
I do not remember	All vaccines	9.77	0.115	-2.37	21.90
	Only compulsory	-4.21	0.506	-16.63	8.20
	None	-5.55	0.168	-13.45	2.34

Region of residence (Ref. = “Center”)						
Northern Italy		All vaccines	0.04	0.979	-3.06	3.15
		Only compulsory	-0.34	0.830	-3.47	2.78
		None	0.30	0.685	-1.15	1.76
Southern Italy & Islands		All vaccines	-2.30	0.170	-5.58	0.98
		Only compulsory	3.18	0.059	-0.12	6.48
		None	-0.88	0.240	-2.36	0.59
Cohort*Experience and timing of Separation						
Within 2 years	All vaccines	1954-1963	-6.68	0.313	-19.64	6.29
	Only Compulsory	1954-1963	8.82	0.183	-4.15	21.78
	None	1954-1963	-2.14	0.000	-2.82	-1.47
	All vaccines	1964-1973	-9.63	0.051	-19.29	0.02
	Only Compulsory	1964-1973	4.69	0.351	-5.17	14.55
	None	1964-1973	4.94	0.076	-0.52	10.41
	All vaccines	1974-1983	-21.52	0.000	-28.78	-14.26
	Only Compulsory	1974-1983	16.55	0.000	8.01	25.09
	None	1974-1983	4.97	0.124	-1.36	11.31
Within 3 to 8 years	All vaccines	1954-1963	-9.55	0.056	-19.35	0.24
	Only Compulsory	1954-1963	5.74	0.257	-4.19	15.68
	None	1954-1963	3.81	0.125	-1.05	8.68
	All vaccines	1964-1973	-6.34	0.078	-13.39	0.71
	Only Compulsory	1964-1973	3.94	0.274	-3.12	11.01
	None	1964-1973	2.40	0.153	-0.89	5.68
	All vaccines	1974-1983	-6.80	0.057	-13.81	0.21
	Only Compulsory	1974-1983	4.45	0.236	-2.90	11.80
	None	1974-1983	2.35	0.330	-2.38	7.08
Within 9 to18 years	All vaccines	1954-1963	-13.75	0.000	-20.83	-6.68
	Only Compulsory	1954-1963	12.12	0.001	4.92	19.32
	None	1954-1963	1.63	0.253	-1.16	4.42
	All vaccines	1964-1973	-8.21	0.007	-14.18	-2.24
	Only Compulsory	1964-1973	6.89	0.025	0.86	12.92
	None	1964-1973	1.32	0.337	-1.37	4.01
	All vaccines	1974-1983	-3.36	0.428	-11.67	4.95
	Only Compulsory	1974-1983	6.75	0.119	-1.74	15.24
	None	1974-1983	-3.39	0.092	-7.33	0.55