Anatomy of a Health Scare: Education, Income and the MMR Controversy in the UK

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Abstract

The measles, mumps and rubella (MMR) controversy provides an interesting case where, for a short period of time, research publicized in the media, suggested a potential risk of serious side-effects associated with the vaccine, where there was also a sharp behavioral response from the public, and where the initial information was subsequently overturned. We consider the controversy from the perspective of health inequalities and the assimilation of information, focusing on whether and how vaccine uptake behavior in the wake of the controversy differed among groups of parents by education and income. Using panel data on the variation in the uptake of the MMR, and other childhood immunizations, across local Health Authority areas we find that the uptake rate of the MMR declined faster in areas where a larger fraction of parents had stayed in education past the age of 18 than in areas with less educated parents. We also find that the same areas reduced their relative uptake of other uncontroversial childhood immunizations, suggesting a "spillover" effect. Using a supplementary data source we find evidence of a corresponding positive income effect, indicating that wealthier parents avoided the MMR dilemma by purchasing single vaccines.

Keywords: Childhood vaccinations, health outcomes, education

JEL Classification: H42, I18

I Introduction

Immunization is a proven tool for controlling and even eradicating disease, sparing people from suffering, disability, and death. The World Health Organization estimates that in 2002, immunization averted about two million deaths. The importance of trust in vaccines can hence hardly be overstated. In this paper we consider a recent episode when trust in one particular vaccine, the combined measles, mumps, and rubella (MMR) vaccine, was eroded due to a number of claims by some researchers, starting in early 1998, linking the vaccine to the development of autism in children. The MMR controversy provides an interesting case where, for a short period of time, research publicized in the media, suggested a potential risk of serious side-effects associated with a standard medical procedure, where there was also a sharp behavioral response from the public, and where the initial information was subsequently overturned. We consider the controversy from the perspective of health inequalities and the diffusion and assimilation of information on advances in medical knowledge, focusing on whether and how vaccine uptake behavior in the wake of the controversy differed among groups of parents with different levels of education and income.

In February 1998 the British medical journal *The Lancet* published a report on twelve children with developmental disorders suggesting a link between autism and their particular gastrointestinal pathologies. While the paper did not claim to prove any link between the syndromes and the MMR vaccine, some of the surveyed parents blamed the combined vaccine, saying that the symptoms had set in days after receiving the immunization. Dr Andrew Wakefield, who led the research, suggested that there was a case for administering the three vaccines separately until further research could rule it out as an environmental trigger. Between 1998 and 2002, the claim of a potential link between the particular vaccine and autism was reiterated on a number of occasions by Wakefield and increasingly in the UK media.

While the government tried consistently to reassure the public about the safety of the vaccine, confidence in the multi-component vaccine declined. As we show below, uptake of the MMR vaccine also declined sharply, dropping by over ten percentage points in five years. However, by

2003, a substantial body of research had failed to verify any link between MMR and autism, and a consensus among researchers emerged, largely echoed in the media, that the vaccine was safe to use.[1] Vaccination levels began to rise again, but not to the level seen before the controversy and not to the level needed to establish herd immunity in the population.[2]

There is mounting evidence suggesting that education and income have causal effects on health outcomes. One of the hypotheses to receive recent attention in the economics literature is that more educated individuals have better understanding of, and more quickly absorb, information on advances in medicine. The MMR controversy provides a useful case for studying individual behavioral responses to new information for several reasons. First, the controversy took place over a relatively short period and the response is known to have been strong. Moreover, the fact that the initial information was subsequently overturned and the decline in uptake reversed gives us confidence that our results are not driven by other unrelated trends. Second, childhood vaccines are provided free of charge through the National Health Service (NHS): parents can either accept or reject them at no monetary cost.[3] Rejecting a given vaccine leaves the child unprotected against the disease while a decision to accept it carries with it a risk of potential side effects for the child.[4] Hence the parents decision problem may be characterized as a binary choice where neither option has any direct cost and where the objective is to choose the option with the least risk for the child's health. Finally, the risk information coming from different sources regarding the safety of the MMR vaccine was, at times, contradictory. Experimental evidence (Viscusi, 1997) suggests that individuals making decisions under such uncertainty give undue weight to high risk information, while low risk information on the same

[1] The original article was formally retracted by the Lancet on February 2, 2010.

[2] Indeed the 2008 and 2009 incidences of measles in the UK was the highest since consistent monitoring began in 1995, prompting the Chief Medical Officer to launch an MMR catch-up programme focused in areas of low take-up http://www.hpa.org.uk/hpr/archives/2009/news2209.htm#msls

[3] There are no vaccination requirements in the UK. This contrasts e.g. with the USA where children must have proof of immunization or immunity to certain infectious diseases before they can start school.

[4] The known side-effects of the MMR are mild fever within a week (one in ten children), febrile convulsion (one in one thousand children), encephalitis (inflammation of the brain, less than one in a million).

outcome, especially when provided by the government, is under-weighted.

For our main analysis we use data on the variation in the uptake of the MMR, and other childhood immunizations, across local Health Authority areas for the years 1997 to 2005, which we combine with corresponding data on education, incomes and other characteristics of the local populations obtained from the Health Survey for England (HSE). We find that the uptake rate of the MMR declined faster in areas where a larger fraction of parents had stayed in education past the age of 18 than in areas with less educated parents. Projections from these estimates suggests that the uptake rate by high educated parents reduced by around 10 percentage points relative to the uptake rate by parents with low education over the period 1998 to 2003, leading to a negative education gradient in uptake at the peak of the controversy. Most of the relative decline in uptake also appears to have occurred during the early stages of the controversy when media attention was relatively low and the uncertainty surrounding the efficacy of the vaccine high. We also find, however, that the uptake of other uncontroversial childhood immunizations declined in relative terms in areas with more educated adults, suggesting a "spillover" effect from the MMR controversy.

After analyzing the area level data, we also consider data from the Millennium Cohort Survey (MCS) which follows a set of children born in the UK within a twelve month period starting in September 2000. These children were due the MMR vaccine at the height of the controversy and the survey therefore provides an excellent opportunity for studying in more detail the behavior of parents at that point in time using micro-level data. Analysis of this data allows us to confirm that there was, at the peak of the controversy, negative education and income gradients in the uptake of the MMR even after controlling for a large range of potentially confounding individual characteristics. Indeed, of all the vaccines freely provided through the NHS, the MMR is the only vaccine for which we observe a significant negative effect of income on uptake. For this vaccine parents had the option of purchasing alternatives, in the form of single vaccines, in the private market, and the MCS allows us to measure this. Here we find evidence of a corresponding positive income effect, indicating that wealthier parents avoided the MMR dilemma by purchasing single vaccines.

The outline of the paper is as follows. Section II provides a background, including a research and media timeline. Section III describes the area-level data and the trends in the uptake of childhood immunizations. Section IV presents the results from the analysis of this data while Section V provides further evidence based on the cohort survey data. Finally, Section VI provides a discussion.

II Background

Literature Review

A positive relationship between education and health is found in most of the literature (see Grossman, 2006 and Cutler et al. (2008) for extensive reviews) as more educated individuals are more efficient producers of health (Grossman, 1972) or make better choices of input mixes (Rosenzweig and Schultz, 1982), possibly due to differences in access and use of health information.[5] Additionally, the education gradient in health may not reflect a causal relationship if both are driven by an omitted variable, such as the discount rate (Fuchs, 1982). Indeed, it may even obtain from reverse causality, where persistent bad health in early years reduces educational investment (Case et al., 2005). The reviews by Grossman and Cutler et al. conclude however that, in general, the link between education and health has a causal component, and that income has only a small role to play in this relationship in developed countries.

Less is known about the channels through which such a causal relationship obtains. As noted in the introduction, one potential channel is that individuals with more education more quickly absorb and respond to new information. We hence focus here on studies that have investigated the role that information plays in shaping the health gradient. Amongst others, Kenkel (1991) demonstrates that education affects health knowledge, while Thomas et al. (1991) show, using the Brazilian Demographic and Health Survey, that most of the effect of maternal education on child height (a proxy for health) can be explained by access to information. Cutler and

[5] Education may alter access, quality or the interpretation of information. Conditional on intensity of the sources of information used, Blinder and Krueger (2004) find that education improves (economic) knowledge.

Llenas-Muney (2007) have an excellent section describing the education gradient in knowledge of various health risks, suggesting that information processing rather than access is the key driver.

A few studies have examined whether more educated individuals more quickly absorb information about risks or new medical technologies.[6] Lleras-Muney and Lichtenberg (2002) find that the more educated are more likely to use drugs recently approved by the Federal Drug Administration, at least among individuals who experience repeat prescriptions, while Lakdawalla and Goldman (2005) estimate larger education gradients in health amongst individuals with chronic conditions where, typically, health information has larger returns.[7]

Our paper concerns the reaction by different groups to emerging health risk information under uncertainty. It is thus directly related to the work of De Walque (2004) on the U.S. Surgeon General's warning on the health risks associated with smoking, and De Walque (2007) on the provision of AIDS information in Uganda. These papers report that the education gradient opens as health information becomes available.[8] One could envisage that the release of information opens the education gradient temporarily as more educated react quicker, but should not have a permanent effect for information that is universally available. Surprisingly then even 30 years after health warnings started to figure prominently on cigarette packages, the gap in smoking by education, which opened when the warnings appeared, does not show any sign of reducing (deWalque, 2004). Relatedly, Lange (2010) argue that merely measuring education and change in behaviour is not sufficient to separately identify the impact of education on subjective

[6]Innovation in health technology could lead to a temporary increase in health Inequality (Victora et al., 2000, Glied and Lleras-Muney, 2008), the effect depending on whether new treatments reduce or increase time investments (Lakdawalla and Goldman, 2005).

[7]Neidell (2004) looks at the effect of air pollution on childhood asthma. He shows that children of lower socio-economic status are not only more exposed to poor air quality, but that they are also more negatively affected by it. On the other hand, he does not find that information in the form of smog alerts reduces asthma any less among lower SES groups.

[8]Similar results are found regarding AIDS/HIV knowledge by Glick and Sahn (2007) for a group of nine African countries.

risk beliefs from demand effects. E.g., in the context of smoking, the more educated may have reduced their smoking not because they better understood the health risks but because they place a greater value on survival and good health.

The MMR controversy has two key features that make it attractive for studying responses to new information. First, the uptake response is known to have been strong and the information was "reversed" within a relatively short period of time. This means that the uptake patterns that we observe across time are unlikely to reflect long-run trends. Second, parents' choice may be viewed as a binary choice between two risky options, neither of which is associated with any direct cost: one that leaves the child unprotected from the disease and one that is associated with potential side-effects. A parent's choice problem then amounts to choosing alternative with the least risky to the child's health according to his/her subjective risk beliefs. Hence demand effects due to heterogeneity in the valuation of health are likely to be small.[9]

The MMR Controversy and a Timeline

In this section we establish a timeline outlining how the MMR controversy developed in the research literature and in the media. The timeline can be summarized as follows. Claims that the MMR was potentially unsafe were made on four occasions between February 1998 and February 2002 by Wakefield and coauthors. Research rejecting any link between the MMR and autism was published in nearly all years, with the majority of studies being published between 2001 and 2003. The media has been identified as a key source of information used by parents concerning potential side-effects of the MMR (Pareek and Pattison, 2000). The media covered all claims of potential side-effects and the majority of the research rejecting such claims. Since most articles report arguments in favor and against MMR, we only measure the intensity of the reporting. Media coverage was particularly intense from spring 2001 through 2004.

[9]See also Section VI for a discussion of potential heterogeneity in risk attitudes.

A Research Timeline

The original paper (Wakefield et al., 1998), published in *The Lancet* in February 1998, reported on twelve children referred to the Royal Free Hospital in London with developmental disorders. The paper described a collection of gastrointestinal conditions said to be evidence of a possible novel syndrome (subsequently referred to as "autistic enterocolitis"). While the paper suggested that the connection between the bowel conditions and autism was real, it did not claim to have proven any link between the MMR vaccine and autism. However, the parents of eight of the twelve children claimed that the onset of the conditions had occurred within days of vaccination. At the press conference before the paper's publication, Dr Wakefield said that he thought it prudent to use single vaccines rather than the triple vaccine until further research could rule it out as an environmental trigger.

The claim of a potential link between the MMR and autism was repeated in April 2000 when Dr Wakefield presented further evidence at a *US Congressional Hearing* showing that tests on 25 children with autism had revealed that 24 had traces of the measles virus in their gut (U.S. House of Representatives, 2000). In a second journal article published in the spring of 2001, Wakefield and Montgomery (2001) claimed that the MMR vaccine had never undergone proper safety tests, and in a third journal article published in the spring of 2002 Wakefield and others provided further evidence of the presence of measles virus in gut samples from children with autism (Uhlmann et al, 2002).

Following the initial claim, a large number of studies, many from epidemiology, failed to confirm any link between the MMR vaccine and autism in particular. E.g Peltola et al. (1998)) traces out all Finnish babies given the MMR since its introduction in 1982, all those who developed gastrointestinal side-effects lasting 24 hours or more. 31 children were identified and it was verified that all recovered and none developed any signs of autistic disorders. Taylor et al. (1999) traced all children diagnosed with autism within the North-East Thames region in the UK since 1979, finding no discontinuity in the incidence of autism around the introduction of the MMR in 1988, no difference in age of diagnosis between vaccinated and unvaccinated children, and no clustering in onset in the months after vaccination. Other studies find no evidence of any discontinuities in the incidence of autism in conjunction with the introduction of the MMR (Gillberg and Heijbel, 1998) or its withdrawal (Honda et al., 2005).[10] Virological studies have similarly found no evidence of persistent measles infection in autistic children (D'Souza et al., 2006).[11]

There have also been a number of research reviews that have rejected any causal link between the MMR and autistic spectrum disorders, most notably by the US Institute of Medicine of the National Academies (2001, 2004), the American Academy of Pediatrics (Halsey et al. 2001), the UK Medical Research Council (2001), and by Demicheli et al. (2005) for the Cochrane Library.

Sources of Information and Media Coverage

It is of interest to consider where parents obtain information about vaccinations. Gellin et al. (2000) conducted a telephone survey in the US with a nationally representative sample of 1,600 expectant parents and parents with young children in 1999. In response to an open-ended question about sources of information ("Where do you get information about immunizations?"), the most frequent answers were doctor; other information sources were newspapers or magazines, books or journals, a nurse, a health clinic, friends or family members, and the internet. In the UK, Pareek and Pattison (2000) studied sources of information in the particular context of the MMR. They found that mothers consulted a wide variety of sources to obtain *general information* about the MMR vaccine, including health professionals, friends, family, and the media. In contrast, mothers predominantly acquired *information about the potential side-effects* of the MMR vaccine from the media rather than from health professionals, with television the

[10] The particular MMR vaccine that had been provided in Japan was withdrawn in 1993 for reasons unrelated to autism and bowel disease.

[11] These five studies are all included in the list below of the main studies rejecting a causal link between the MMR and autism. That list contains an additional eight studies which are Kaye et al. (2001), Farrington et al. (2001), Taylor et al. (2002), Black et al. (2002), Donald and Muthu (2002), Madsen et al. (2002), Miller et al. (2003), and Smeeth et al (2004). The list of main studies rejecting a causal link was compiled from the summaries of the research provided by the NHS and the BBC.

most commonly cited source of information (cited by 35 percent of mothers).

Given this apparent importance of the media in the context of the MMR it is useful to establish the volume of media coverage as part of the general timeline. To this end, we measured the coverage of the controversy using the online editions of BBC news and four major daily newspapers (the Guardian, the Independent, the Daily Mail, and the Telegraph), for each source collecting all related articles.[12] For BBC news, articles are available online all the way from the start of the controversy. For the newspapers, articles are generally available online since 1999. Figure 1 highlights the number of relevant articles, by quarter, appearing in BBC news online in each of the years 1998 to 2006. The figure also highlights the timing of (i) the four claims of a potential risk associated with the MMR noted above, (ii) the main research studies indicating no causal effect of MMR on autism, and (iii) the four main research reviews noted above.

A noticeable feature of the timing of the media's coverage was the relatively small number of articles appearing during 1998 and 1999 – a total of 15 articles appearing in BBC news online over two years. This contrasts with the sharp increase in media coverage starting in the spring of 2001, with 20 articles appearing in a single quarter. The newspaper coverage was very similar in terms of volume. In terms of content, all four instances of claims of potential side-effects were reported; indeed, the two spikes in media coverage in the spring of 2001 and 2002 were sparked by the two publications appearing at those times (Wakefield and Montgomery, 2001 and Uhlmann et al, 2002). The majority of the aforementioned main studies finding no link between the MMR and autism were also reported in the media.

III The Data

We first use area-level data. The areas that will serve as our unit of observation are 95 so-called Health Authorities (HA). The HAs were introduced in April 1996 and were then the lowest health administrative level. In 1999 a lower level of administration, known as the Primary Care

[12]The above data is only intended to give an indication of the relative media coverage over time. It will not be explicitly used in the analysis below, primarily because it is difficult to obtain a fully satisfactory measure of media coverage (e.g. average minutes on televised news).

Organizations (PCO), was established. In June 2003 the HAs were abolished. However, the three hundred or so PCOs can be aggregated up to reconstruct the HAs after the latter had been abolished.[13]

The childhood immunization schedule for children under the age of two in the UK is as follows. Between the ages of two and four months, children receive a primary course (consisting of three doses) of vaccines against diphtheria, tetanus, pertussis (whooping cough), polio and haemophilus influenzae type b ("hib"). Then at around 13 months a first dose of the measles, mumps and rubella (MMR) joint vaccine is administered. All these vaccines are provided free of charge through the NHS. In particular, the NHS does not provide single measles, mumps and rubella vaccines. Any parent who would prefer to have singles vaccines of any of these three would need to obtain these privately at a significant cost (see below).[14]

The data on area-level uptake rates, available through the NHS Information Centre, is collected by the Health Protection Agency. Information is collected about the immunization status of all children who reach their second birthday (and other ages) within the specific year, where the year refers to the period April 1st to March 31st of the following year; specifically it reports the fraction of children resident in the geographical unit having received the first dose of the MMR and the fraction of children completing a primary course of the other immunizations.[15]

It is hence important to keep three things in mind. First, the "year" refers to the administrative period April to March. Second, there is nearly a year's gap between the parental decision on the MMR and the data collection; hence e.g. the MMR uptake rate in the 2005 data refers to children who reached their second birthday between April 2005 and March 2006 and who were hence eligible for the MMR between May 2004 and April 2005. Finally, there is up to a year's gap between the parental decision on the other vaccines and the MMR.

[13]In 2006 the PCOs were reduced to 152; after this last restructuring it is possible to reconstruct only a subset of the HAs.

[14]The data thus contains information about vaccinations obtained through the NHS, not those obtained through the private market. Hence the statistics may underestimate the total vaccination rate (see below).

[15]Data on immunization uptake is missing for three London HAs in 2005 due to IT problems in the data collection process.

We combine uptake data with information about the characteristics of the local populations. To this end we use data from the HSE, which is an annual cross-sectional survey of individuals monitoring trends in the nation's health. We use the HSE since it is the only survey in the UK that identifies household area information in terms of the administrative health geography.[16] Unfortunately, income data is only available in the HSE from 1997 onwards. Hence we will focus on the years 1997 to 2005.

Demographic Characteristics

We start by establishing that the HAs are diverse. We include all adults aged 16-55 in the HSE's general population sample. In order to more precisely characterize the adult population of parenting age we give each observed adult an age-related weight, where the weight is the value of an empirical density function of age among parents to newborn babies.[17] Pooling across years, a total of 63,963 men and women could be allocated to HAs. With 95 areas and nine years, this implies that the average number of adults per cell is 75.[18]

Two key demographic variables for our purposes are education and household income. We focus on simple binary measure of education – the fraction of adults remaining in education until at least age 19, which we label as "high" education.[19] Household income measures not only earnings but also benefit income, maintenance, and interest from savings etc. We also include a number of further time-varying area-level characteristics of the adults of parenting

[16] We would like to thank the National Centre for Social Research for constructing and providing this information for all years.

[17] The alternative of using only observed parents with small children would have lead to unusably small cell sizes. The frequency distribution of age among parents to newborn children is obtained from the Millennium Cohort Survey which is described below.

[18] The average number of babies in an area-year cell is 6,106 with a standard deviation of 2,629. Most of this variation is due to area-size differences: the standard deviation in number of babies across areas after pooling across years is 2,604.

[19] We chose this particular age cutoff since finishing at age 19 or above would, in the UK, generally correspond to obtaining some higher education qualification.

age, some of which have previously been found to be related to uptake of childhood vaccines (see e.g. Samad et al. (2006)); these include controls for ethnic composition, the average number of children per household, the fraction of females that are lone parents, the fraction of adults that ever smoked (since smokers may have different health risk attitudes), and the share of immigrants in the local population.

Since parents obtain information about vaccinations from health professionals, – not least their General Practitioners/physicians (GPs) – we include a set of variables to control for the heterogeneity in the GP population.[20] First, we include the number of GPs per thousand babies. Second, since the advice that GPs give may be related to their experience we control for the age composition of the local GP population using three age-bands (below 35, 35-64, and 65 or older). Male and female GPs may advice parents differently; hence we control for the gender composition of the local GP population. In order to proxy for the demand for health care we also measure the average age of adults living in the area.

The first column of Table 1 shows the mean across all areas and years and the standard deviation across area-year cells. The standard deviations indicate substantial diversity. The second column of Table 1 shows the aggregate annual trend in each variable (obtained by regressing the annual means on time). The fact that several variables exhibit strong time trends reinforces the importance of measuring the variation across time, i.e. to allow the explanatory variables to be time-varying.

Uptake of Childhood Immunizations

The MMR is the childhood immunization that has seen the largest variation in uptake over the last fifteen years. This is illustrated in the left panel of Figure 2 which shows how the uptake rate of the MMR has varied since 1992. The vertical lines identify four phases: (i) a pre-controversy phase, (ii) an early controversy phase (during which there was some decline and low media coverage), (iii) a phase of sharp decline and intense media coverage, and (iv) a recovery phase.

[20]We would like to thank the NHS Information Centre for kindly providing the detailed data on the GP population.

The right panel shows the corresponding uptake of the other childhood vaccines.[21] The figure illustrates how the uptake of the MMR was already, prior to the controversy, low relative to that of the other vaccines and below the target rate of 95 percent required for herd immunity against measles, mumps and rubella. The uptake of the MMR drops in the 1998 data. This data point contains children born between April 1996 and March 1997; since the MMR is administered after the age of 13 months, this means that little less than one third of the children that make up this data point would have been due the MMR in February 1998 or later. After this initial drop, the MMR uptake rate levelled off somewhat in the 1999 and 2000 data; it then dropped again sharply in the 2001 to 2003 data before finally picking up in the last two years of data. Even though the uptake of the other vaccines has been more stable, it is clear that they too have shown some variation over time; indeed, in all cases we see a general reduction lasting until 2004.

The trend in the uptake rate for the MMR is closely related to the perceived safety of the vaccine. Parental attitudes towards immunizations have been tracked across time through a monitoring programme that surveys around 2,000 mothers per year (Yarwood et al. 2005, Smith et al. 2007). The respondents are asked, inter alia, to assess the safety of a number of immunizations by rating them on a four point scale: 'completely safe', 'slight risk', 'moderate risk' and 'high risk'. To illustrate the strong correspondence between uptake and perceived safety, Figure 2 (left panel, right scale) illustrates the proportion of mothers saying that the MMR was completely safe or posing a slight risk. The strong correlation between perceived safety and uptake of the MMR strengthens the idea that the measured changes in uptake over time are mainly driven by changes in parental beliefs about the safety of the vaccine.

Figure 3 shows the uptake of the MMR across HAs prior to the controversy and at its peak. The figure shows how, in the 1997 data, there were no areas with uptake rates below 75 percent with the vast majority of areas at 90 percent or above. In contrast, in the 2003 data, all areas except one have uptake rates less than 90 percent and 15 areas are below 75 percent.

[21]The Hib vaccine was introduced in 1992. It's first measured uptake in 1993, which was 75.1 percent, is not included in the figure order to make the other trends more visible.

IV The Model and Results

The main hypothesis that we wish to test is whether the change in an area's uptake rate, during the controversy, is correlated with fraction of its population that has a high level of education. However, we do not want to focus too narrowly on education. One option available to parents rejecting the MMR would be to purchase single vaccines (see below). However, single vaccines would come at a substantial cost to the parents, which would suggest a potentially important role played by household income.

In order to consider the role of education and household income in shaping the response to the MMR controversy we adopt a flexible empirical model where education and income potentially affect the time-path of the MMR uptake rate. We model the uptake rate in area j at time t as follows:

$$MMR_{jt} = \delta_t D_t + \zeta_j D_j + \alpha^z z_{jt} + \alpha^y y_{jt} + \boldsymbol{\alpha}^x \mathbf{x}_{jt} + \beta_t^z D_t z_{jt} + \beta_t^y D_t y_{jt} + \varepsilon_{it}. \tag{1}$$

In this specification D_t is a dummy variable for the year being t; hence δ_t is a year fixed-effect (with 1997 as the omitted reference year). Similarly, D_j is a dummy for area j; hence ζ_j is a HA area fixed effect. The area fixed effects control for any time-invariant differences across HAs associated with level differences in uptake rates. The variable z_{jt} measures the fraction of adults of parenting age in area j at time t who stayed on in education until age 19 or above; hence α^z measures the impact of education on the baseline uptake rate. Similarly, y_{jt} is the average household income in area j at time t; hence α^y measures its impact on the baseline uptake rate. The vector $\mathbf{x}_{jt}$ contains our remaining controls; the vector $\boldsymbol{\alpha}^x$ hence measures the impact of these variables on the uptake rate.

Our main interest concerns the β coefficients; these are the coefficients on the interactions between education and income, respectively, with the year dummies. These measure how the two key area characteristics – the fraction of adults with high education and average household income – affected an area's trend in uptake. In all our estimates of equation (1) the observations are weighted by the number of babies and we apply a robust fixed effects estimator (Wooldridge, 2002, Ch. 10).

Analysis of the Uptake of the MMR

Table 2 presents estimates of various versions of equation (1), with the dependent variable measured in percentage points. The first specification includes only year- and area-fixed-effects. The time dummies in this specification are very similar to the aggregate trend observed in figure 2: an initial drop of 2-3 percentage points in 1998 to 2000 was followed by a sharp drop in 2001 to 2003, making the total drop between 1997 and 2003 in the order of eleven percentage points, and followed by an increase of about 4 percentage points in the last two years of data.

The second specification adds education to the regression. Educational attainment has a large positive and significant effect, close to nine percentage points, on the baseline uptake rate. The coefficients on the year dummies now measure the change in the uptake rate across time for a (hypothetical) area with no parents with high education. The coefficients on the interactions between education and the year dummies measure the estimated *additional* response across time as the area is switched to one with only highly educated parents.

These results suggest that areas characterized by low education responded relatively less to the MMR controversy, both in its initial phase and at its peak. For an area with no educated parents the projected reduction in uptake between 1999 to 2001 is about half of the observed aggregate reduction in uptake, and at its lowest point the area's uptake rate would be about 8 percentage points lower than its uptake prior to the controversy. In contrast, the results indicate a much stronger response by high educated parents, increasing rapidly from a five percent reduction in 1998 to a nearly 17 percentage point reduction by 2001 and 21 percentage points reduction by 2003.

The third specification in Table 2 adds household income as an explanatory variable. Hence whereas specification 2 considers the effect of education on uptake behavior, including its indirect effect via higher income, the third specification separates out the income effect from the education effect. Controlling for income generally reduces the estimated response by low-educated areas, particularly for the years 1998 to 2000. Only from 2002 onwards does the model predict any sizeable and statistically significant response in an area with no highly educated parents.

In contrast, the estimated additional responses in areas characterized by high education remain negative and sizeable from 1999 onwards and statistically significant for the years around the height of the controversy.

Higher income, while having zero effects on the baseline uptake rate, appears to be associated with a faster decline in uptake for all years, but is only statistically significantly so for the years around the height of the controversy. We argue below, based on results from the MCS, that the income effect is consistent with some richer parents declining the freely provided combined vaccine in favor of buying single vaccines on the market. However, the size of the income responses is fairly modest: at the height of the controversy, increasing household income from the 25th to the 75th percentile of the distribution (at household level) would decrease the uptake rate by little less than four percentage points.

The fourth specification in Table 2 adds further time-varying controls. Adding these controls has a very small impact on the other estimated coefficients. As for the controls themselves the results suggest a positive effect of the number of GPs and, possibly, a lower uptake among blacks, immigrants and smokers; however the coefficients are only significant at the 10 percent level. Based on this, most general, specification we would conclude that a six percentage point *positive* education gradient that existed prior to the controversy had, by 2001 to 2003, been eliminated and turned to a one to three percentage point *negative* education gradient.[22]

[22] A few further specifications were also tried out. First, the uptake response to the controversy could potentially be related to local infection risk. To explore this we estimated a specification where we used data on uptake in 1996 (as a proxy for the local immunity rate at the onset of the controversy) interacted with time. These interactions were not statistically significant. Second, due to concern about small cell sizes when characterizing the local populations we also experimented with specifications where we replaced the annual values of the variables with their moving averages. Third, rather than including all demographic variable we ran a specification where we only included variables that were statistically significant. Neither of these three variations on the main specification had any substantial impact on the key estimate coefficients. As a further robustness check, we also considered removing the area fixed-effects, thus allowing identification from across-area variation in the background variables. Doing so increased the estimated relative response by high educated parents, leading to an "over-prediction" of the negative education gradient relative to what we observe in the MCS data below.

The estimates suggest that the decrease in relative uptake of the MMR for areas characterized by relatively high levels of education was particularly pronounced in the early stages of the controversy: this is reflected in the coefficients on the interactions between time and education generally growing (in absolute value) between 1998 and 2001 and becoming strongly significant in the last of these years. In contrast, from 2001 until 2003 the estimates suggest that the rate of decline in uptake was largely the same in areas with different levels of education. In order to consider this in more detail, and also for parsimony, we re-estimate the model using a set of linear splines instead of year dummies, allowing for four subperiods with knots at 1998, 2000, 2003. As noted above 1998 is the first year of data for which some children – about one-third – would have been due the MMR after the start of the controversy. The choice of 2000 as a second knot is natural for two reasons. First, from the aggregate data we know that uptake decreased only slowly up until 2000 and fell sharply thereafter (see Figure 2). Second, from the timeline we know that media coverage of the controversy was relatively low until the spring of 2001. The choice of 2003 as a knot is natural since this is the year when the MMR uptake reaches it lowest point. The results are shown in Table 3. Focusing on the main specification (4), the coefficient on each subperiod in this regression measures the annual change in the vaccine uptake rate in a (hypothetical) area where no parents have high education. Similarly, the coefficient on the interactions between education and a given subperiod measures the additional annual change in uptake as the area is switched to having only parents with high education. In the spline specification, again, there is no evidence of any trend in uptake of the MMR prior to 1998. The main result is that areas with more educated parents sharply reduced their relative uptake rates in the second subperiod, i.e. from 1998 onwards. In contrast, the estimates suggests that an area without highly educated parents would not have responded at all until after 2000 (i.e. the first significant response occurs in the third subperiod). Moreover, in the third and fourth subperiods the change in an area's uptake rate is not related to the level of education of its population.[23] In line with the results from Table 2, projections based on the estimated spline

[23] Two previous studies from other disciplines present related results partially based on the same data. Middleton and Baker (2003) focus on a subset of 60 HAs for the period 1991-2001, grouping areas into "deprived", "affluent",

model in the last column of Table 3 imply that there was a sizeable positive education gradient prior to the onset of the controversy but that this had turned into a negative gradient of about two to three percentage points by the peak of the controversy.[24]

Other Immunizations

While Figure 2 shows the dramatic decline and subsequent recovery in uptake for the MMR, it also suggests that there have also been smaller declines in the uptake of the other childhood immunizations. Given that the controversy was MMR-specific these declines are somewhat puzzling. Two main explanations can be conceived. First, it could be that these declines were unrelated to the MMR controversy and were driven by changes in the demographic composition of the population. Second, there could be "spillover effects" in the sense that some parents, as a response to the MMR controversy, also rejected other "uncontroversial" vaccines. We will argue here that the second explanation is more likely.

Three predictions would be associated with the spillover hypothesis. If the decline in the other childhood vaccines were due to spillover effects of the MMR controversy, then we should see that (i) the change in behavior should occur within the same subgroups of the population, (ii) the time pattern of the uptake rates for the other vaccines should be similar to that for the

"neither" according to a deprivation index. They find that after 1997 there was a faster decline in the more affluent areas. Wright and Polack (2005) also use data on uptake rates at the HA level which they combine with data on demographic characteristics obtained primarily from the 2001 census. They estimate a model where the dependent variable is the change in uptake rate between 1997 and 2003 – an implicit area-fixed effect model – and find that having no qualifications is associated with a lower decline in uptake. However the authors measure the educational attainment of the economically active population rather than that of the adult population of parenting age which could result in a substantial bias.

[24]In the regressions presented in Tables 2 and 3, we only consider differential responses to the controversy by education and income level. We have also explored interacting each of the remaining demographic control variables with time. We found that no other variable generated any dynamic response that could be related to the timing of the controversy (and the overwhelming majority were statistically insignificant). Moreover, including interactions with these other variables, one at a time, generally had negligible impacts on the estimated effects of education.

MMR, possibly with an extra lag of one year due to the nature of the data collection process,[25] (iii) since the option of purchasing single vaccines in the private market applied specifically to the MMR, we should expect to see income effects that are particular to that vaccine.

In order to explore these predictions we estimate the same equation (1), this time on the other childhood immunizations. All regressions use the same specification as specification (4) in Table 2 and the results are presented in Table 4.

The predictions are largely borne out. First, the results indicate that the changes in uptake behavior are particularly strong in areas with relatively highly educated populations.

Among the coefficients on time (which represent the change over time in uptake in a fictive area without any highly educated parents) there are generally speaking no statistical effects, although the point estimates suggest a decline in the uptake rate of about three percentage points between 2000 and 2005. In contrast, the coefficients on the interactions between the year dummies and education are, from 1999 onwards, negative and, for the last four years in particular, always statistically significant, indicating an additional decline of around six to seven percentage points. Second, with respect to timing, there is no negative response in any group in 1998; this is consistent with the spillover hypothesis since the decisions that are measured in the 1998 data would have been taken between the summer of 1996 and the summer of 1997, i.e. before the start of the controversy. Finally, with respect to income, the estimated effects on the change in uptake across time are very small and generally not statistically significant.

It could potentially be argued that the downward relative trend in the uptake of vaccinations by high educated parents simply reflects a more general phenomenon of reducing inequality of access and use of health care. This is unlikely for two reasons. First, the vaccinations saw absolute reductions in uptake. Second, the decline in relative uptake in highly educated areas appears to be particular to childhood vaccinations. To illustrate this we present in the last column of Table 4 a corresponding regression for the rate of cervical screening tests ("smear

[25] Recall that there is one year's lag between the MMR decision and the data collection and nearly a two-year lag between the parental decision on the other vaccines and the data collection. Note also that we cannot distinguish between cohort effects and pure year effects.

tests").[26] Smear tests provide a suitable comparison in that women (aged 25 to 65) are invited to participate in a programme designed to prevent a particular disease; moreover, the uptake rate is similar to that for childhood vaccinations and there was no controversy about its efficacy. Regressions of the uptake rate for the smear test shows a pattern that is directly opposite to that for childhood vaccinations: high education is associated with both a relative and absolute increase in uptake.

Hence, we conclude that, in line with the spillover hypothesis, we see changes in behavior that are particularly strong in high education groups, occurring only for those due for the early childhood vaccines from 1998 onwards, and with little role played by income.

V Further Evidence

In this section we supplement our earlier results with further evidence using data from the MCS. The MCS follows the lives of a set of children born in England between September 2000 and August 2001.[27] The survey design implies that we cannot use the MCS to explore the dynamic responses to the MMR controversy. However, since the MCS cohort members were due the MMR between the autumn of 2001 and the autumn of 2002 the survey is ideal for considering in detail the behavior of parents precisely at the height of the controversy.[28]

[26]We would like to thank Amanda Gosling for the suggestion to look at the uptake of smear tests. Data limitations prevented us from looking at other alternative services such as e.g. the use of anaesthetics during labor.

[27]We use information from the first two waves when the children where 9 and 36 months old, respectively.

[28]The uptake of the MMR in the MCS is significantly higher than the corresponding national average at the time. There are two potential explanations for this. First, in the MCS the question is asked at the age of three which is higher than the age at which the NHS data is collected; hence insofar as parents reacted to the controversy by delaying the uptake of the MMR we would expect a higher observed uptake rate in the MCS. Evidence that the controversy has led parents to delay their uptake of the MMR is provided in Cameron et al. (2007). Second, given that the social norm is to vaccinate there is a possibility that parents may over-report their uptake. Available evidence, however, does not suggest that parental over-reporting of childhood immunizations is generally unequally socially distributed (Suarez, Simpson, and Smith, 1997). The "Hib Extra" is a particular booster introduced after routine monitoring revealed that the number of cases of hib had gone up in 2001 and

Our justification for using the MSC is threefold. First, it allows us to explore in greater detail whether there was, at the height of the controversy, a negative education gradient in MMR uptake as predicted by the main model presented above. Second, due to its richness, the MCS data allows us to control for a much wider set of potentially confounding factors. Third, the MCS data also contains information about purchases of single vaccines by parents as an alternative to the MMR; this allows us to consider in more detail whether the option of single vaccines lies behind the negative income effect observed only for the MMR.

The Millennium Cohort Survey Data

Since our earlier analysis pertained to English HAs we use all MCS children born in England.[29] Since the information on fathers is often missing or incomplete we will focus on the personal characteristics of the cohort member's mother. In order to conform with the previous analysis, we use the same measure of education, i.e. staying on in full-time education until at least age 19. The MCS has a rich set of variables that allow us to control for a range of potentially confounding factors. We include information on ethnicity, the mother's age when the child was born, (equivalized) household income, the gender of the child, the marital status of the mother, whether English is spoken in the household, smoking and drinking habits of the mother, the number of siblings of the cohort member at the time of birth, whether the child has been in private childcare (by age three), and whether or not the household had an internet connection (either in the house or through work), frequency of contact with the grandmother, the mother's perception of the quality of the neighborhood, whether the mother worked in the NHS before the birth of the child, whether the mother worked in a "scientific occupation", whether she voted for the Tory party in the 2001 general election, whether the mother is catholic or muslim. We also control for area-effects using the nine Government Office Regions – the lowest level of area information available in the survey. Descriptive statistics on the sample used are provided in

2002.

[29]The MCS oversampled some minority groups; we only use the main representative sample.

Table 5.[30]

Immunization Takeup at the Height of the Controversy

Table 6 (first column) provides the results from a probit model of the MMR uptake. The regression confirms the lower MMR uptake by high educated parents; the point estimate of a 2.5 percentage points gap is more or less identical to that predicted by the models in fourth columns of Tables 2 and 3 for the relevant years (2002 and 2003). This observed negative education gradient for the MMR contrasts with that for the other immunizations for which there are, largely speaking, no observed differences in uptake rates among high- and low educated mothers. This latter absence of a positive gradient is also consistent with the analysis above, that prior to the controversy there was, for each of the other main vaccines, a four to five percentage positive education gradient which, by the time of the MCS cohort, had disappeared. The estimated impact of household income on MMR uptake is negative, as in the above analysis. The point estimate suggests that increasing income so as to move a family from 25th to the 75th percentile of the income distribution would reduce the MMR uptake by around two percentage points. A negative income effect for the MMR sharply contrasts with the estimates for the other vaccines for which we find either zero or positive income effects.

Among other background factors, we note that never married mothers appear to have a lower uptake of vaccines than currently married mothers, although the effect is not precisely estimated for the MMR. Ethnicity has a substantial impact on the uptake of the MMR but not on the other vaccines; for the MMR, whites have an 8 to 9 percentage point lower uptake rate than either asians or blacks. The gender of the baby has no significant impact on the uptake of any vaccine, except possibly for a lower uptake of the MMR for boys. The presence of older siblings has a positive effect on the uptake of the MMR, but not for the other vaccines (except for the case of four or more siblings where we observed negative impacts). This suggests that mothers who had previous experience with the MMR may have been less influenced by the controversy.

[30]The variables measuring the frequency of contact with the grandmother and the mother's perception of the quality of the area are presented here in binary form; in the regressions a finer set of categories are used.

Internet access, as a further source of information, was found to have a negative effect on the uptake of the MMR, but not for the other vaccines.

Finally, in order to check for a trend within the twelve month sampling period, we divided the period into three subperiods of equal length according to month of birth (subperiod 1 = September - December 2000, subperiod 2 = January - April 2001, subperiod 3 = May - August 2001). The children born in the first subperiod would have been eligible for the MMR in the autumn of 2001 whereas those children born in the subsequent two subperiods would have been due the MMR starting in January 2002. The estimates suggest that the MMR uptake rate was falling over time. The estimated drop in uptake from the first subperiod to the third of two percentage points would translate into an annual trend of 3 percentage points which is similar to the two percentage annual reduction observed in the aggregate data.[31] Most of the drop in the uptake rate occurred from the first to the second subperiod. This is consistent with the due date for the MMR for the first subgroup occurring before the peak in the media attention in the first quarter of 2002.

In Table 7 we provide further robustness checks on the education and income effects by considering alternative specifications. Specification (1) is the same as the same as in column 1 in Table 6 except it excludes income, while Specification (2) instead excludes education. In each case the estimated effect is increased, as we would expect given that income and education are positively correlated and both are negatively associated with MMR uptake.

Specification (3) adds additional covariates. These include indicators for whether the child has attended private childcare (which may increase the pressure on the parent to have the child vaccinated), whether English is not spoken at home (since language barriers may make parents less susceptible to controversies covered in the media), the child has some long-standing illness or asthma, whether there is frequent contact with the grandmother (since older generations may have more experience with the diseases against which the vaccines offer protection), the mother's

[31] We have also interacted the subperiods with mother's education; this reveals no difference in trends, which is also consistent with the parallel trends for the two educational groups around that time estimated using the area-level data (see Table 2).

perceptions of the suitability of the area for bringing up children, whether the mother voted for the Tory party in the last general election (which is likely to be related to attitudes towards public services), whether the mother worked in the NHS or worked in a "scientific" occupation, and whether she is catholic or muslim. Adding these covariates slightly increases the estimated effects of education.

Parents with different levels of education may differ systematically with respect to their willingness to take health risks; if so it could be that the estimated negative effect of education partly reflects unobserved differences in risk attitudes. In order to consider this, specification (4) adds indicators of the mother's current smoking and drinking behavior as proxies for health risk attitudes. Introducing these proxies slightly reduces the estimated effect of education, but does not remove the negative education gradient.

Similarly, it could be that parents differ in unobserved generic preferences towards immunization and that those preferences are correlated with education; if so, we should expect that the parents who choose not to take up the MMR would also be more likely to not take up the other childhood vaccines. To consider this, specification (5) add indicators for the number of previous vaccinations administered to the same child; the coefficients for education and income then measure the impact on the uptake of the MMR for parents who behaved in the same way with respect to the vaccines provided at an earlier age. Controlling for earlier vaccine uptake for the same child again has a minor impact on the estimated education, and does not remove the negative education gradient. Specification (6) includes all the above.[32]

The Option of Single Vaccines

A parent who does not take up the MMR has two options: either to let the child be unvaccinated or to obtain single vaccines. We argued above that the significant negative income effect,

[32] In addition to the above regressions we have also considered specifications where education is disaggregated into five levels of qualifications, corresponding to the standard ISCED classification. The results from these regressions, which are available from the corresponding author by request, indicate a threshold effect at qualifications that are typically obtained at the age of 18 or above.

observed only for the MMR, is likely to be, at least in part, driven by the single vaccines option.

No single measles, mumps or rubella vaccines are licensed for either manufacture or general sale in the UK. Nevertheless, single vaccines can be ordered on a named-patient basis through private clinics. A typical price for a single jab (including consultation) is currently in the order of £80 - £100; hence the cost of a complete set of three single jabs is substantial, typically well above £200. The MCS provides an opportunity to document the demand for single vaccines at the height of the controversy since parents were queried about this in the survey interview. The percent of children in the MCS having had single jabs of measles, mumps and rubella are 5.3, 2.9 and 4.9 percent respectively; that corresponds to 24 to 45 percent of parents who rejected the MMR.

Our main aim here is to document the demand for single vaccines, especially the roles played by income and education. Table 8 shows the results of three probit regressions. In the first column the population is all children and the outcome is having had at least one single vaccine; the second regression considers the probability of having had at least one single vaccine conditional on not taking up the MMR; the third regression considers the probability of having had a complete set of three single vaccines conditional on having had at least one single jab.

The first regression is essentially the mirror image of the regression for the uptake of the MMR presented in Table 6 above. Income has a significant positive effect; mother's education has a positive sign but is not statistically significant. A strong income effect is also evident when we consider the choice between obtaining single jabs versus letting the child be unvaccinated conditional on turning down the MMR (column 2); moving a family from the bottom income quartile to the top income quartile increases the probability of the family choosing single jabs by up to 30 percentage points. The final column considers the choices made by those parents who decided to obtain at least one single jab. Here there is some weak evidence that higher income implies a higher probability of obtaining a complete set of three vaccines. There is also some suggestion that more educated mothers were more selective and more often chose not to take up one or more vaccine (typically the mumps vaccine).

VI Discussion

Given the global role for immunization in controlling and even eradicating disease, the importance of trust in vaccines can hence hardly be overstated. In this paper we have considered a recent episode when trust in one particular vaccine, the combined measles, mumps, and rubella (MMR) vaccine, was eroded due to a number of claims by some researchers, starting in early 1998, linking the vaccine to the development of autism in children. Over the following five years, the claims of a link were met with counterclaims and with government reassurances about the safety of the vaccine; by 2003 the claims had been thoroughly and resoundingly rejected by subsequent research. The controversy spread confusion among parents: the perceived safety of the vaccine declined sharply between 1998 and 2002, as did the uptake of the freely provided multi-component vaccine.

We considered this episode from the point of view of the debate on the link between education and health. One argument put forward in that debate is that more educated individuals more quickly absorb new health related information. We hence hypothesized that the decline of the MMR uptake rate should have been more pronounced among high educated parents.[33] Using area-level data we found that areas with more highly educated populations saw larger reductions in uptake: projections based on our estimates suggest that, from the start- to the peak of the controversy, high educated parents reduced their uptake rate by about 10 percent more than did low educated parents. In fact, the relative decline in uptake for the high educated parents appear to have been so strong that what used to be a significant positive education gradient in uptake turned into a negative one. Interestingly we also find that most of the relative decline in uptake by high educated parents occurred in the first two years of the controversy – a period in which media's coverage of the story was relatively low.[34]

[33] One would also expect that the recovery in the uptake rates should be more pronounced for high educated parents once it was clear that the claims could not be substantiated. While the data does suggest that this may indeed have been the case, it cannot be verified with only two years of data for the recovery phase.

[34] There is no indication that the controversy had any effect on fertility decisions. Fertility in the UK was declining throughout the 1990s but started increasing around 2001. Brewer, Ratcliffe and Smith (2007) suggest

A differential response by high- and low educated parents can have obtained through several different channels: (1) education may be associated with a higher degree of awareness in the sense that the news more frequently reached high educated parents; (ii) more educated parents may have perceived the information differently than low educated parents; (iii) more educated parents may have absorbed and perceived the new information in the same way as low educated parents but responded differently in terms of uptake behaviour. Regarding awareness, given that access to television is nearly universal everyone would, in principal, have had access to the information.[35] Equal access, however, does not imply that individuals follow and absorb news with equal intensity.[36] Hence using the current data we cannot discriminate between the first and the second channel.

The third channel would require parents to differ in some other characteristic, correlated with education, that could induce differential responses. As noted above, the choice facing parents may be viewed as a choice between two options, each with negligible direct costs, but leading to different potential risks to the child's health. A prime candidate for difference in response behaviour would then be heterogeneity in risk-attitudes. However, we consider this unlikely to be the main explanation for several reasons. For one, there is no consensus in the empirical literature that education is positively correlated with risk-aversion (see e.g. Harrison et al., 2007 and Shroeder et al., 2007)). Moreover, including proxies for the mother's health risk behaviors had only a minor impact on the estimated effect of education on MMR uptake in the MCS data. Also, the finding that the relative decline in the uptake of the MMR by high educated parents was particularly pronounced in the early phase of the controversy when media coverage was low suggest that the observed differential responses were due to high educated parents picking up

that part of this reversal in the fertility trend may be attributed to changes in tax-benefit policy.

[35]At present 99 percent of UK households own a TV set (General Household Survey, 2006).

[36]Another source of information are GPs. However, the possibility that high and low educated parents would have been systematically provided different information by their GPs is relatively unlikely: GPs (who are under contract with the NHS) were not allowed to go against the official policy and recommend parents not to take up the MMR; moreover, they had financial incentives for encouraging MMR uptake through a policy that provided bonuses for achieving target levels.

the story earlier. Finally, the UK surveys tracking parental attitudes towards vaccines suggest that perceptions of the safety of the vaccine did indeed develop differently across parents of different social grades of parents in a way that is consistent with our main hypothesis (Smith et al., 2007).

Our findings are clearly consistent with the hypothesis that high educated parents absorbed the new information more rapidly. It does not, on the other hand, prove rationality of parents' behavior. Indeed, we found evidence that the controversy generated a "spillover" effect, leading high educated parents to also reduce their uptake of other "uncontroversial" vaccines. The viability of such a spillover effect may have stemmed from an argument in the debate that "too many" immunizations in general, and multi-component vaccines in particular, could "overload" the child's immune system.[37] Nevertheless, given that the claims of a link to autism pertained particularly to the MMR, the existence of a spillover effect onto other vaccines suggests a possible element of "alarmist reaction". This possibility has also been considered in the behavioral-theoretical literature: Viscusi (1997) uses experimental data to show that individuals give undue weight to high risk information and that the low risk information, especially when provided by the government, is under-weighted. As noted by Viscusi (1997) "the media and advocacy groups often highlight the worst case scenarios, which will tend to intensify the kinds of biases [in risk assessment] observed".

If, generally, the rate at which individuals absorb new health technology information is indeed related to their levels of education, this has important policy implications. In particular, it suggests that a policy that attempts to improve health outcomes by providing more information may induce larger inequalities in health outcomes, at least in the short run. Moreover, the current case is particular in that individuals obtained very different risk assessments from different sources. Gaining a deeper understanding of how people react when different information sources provide different risk assessments is important. The institutional setup in this context can also

[37]Indeed, the "overload" theory was articulated by Dr Wakefield in the media; when interviewed on the BBC Panorama program on February 3, 2002, he argued that: "You do not combine three live viruses into one vaccine and assume that it is a benign process."

matter. Information provided by the government may not necessarily be the most effective for tackling cases such as the MMR controversy; institutions representing the research community that are independent of government, such as the American National Academies, or the National Institute for Health and Clinical Excellence in the UK, may be more successful in convincing the public about which research claims are generally supported by evidence and which are not.

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Table 1: Characteristics of the Adult Population of Parenting Age in the Health Survey for England, 1997 to 2005.

Variable	**Aggregate Mean** (Std. Dev. Across Area-Year Cells)	**Annual Trend** (Std. Err.)
Education: LFE at age $\geq$ 19 (%)	28.1 (16.9)	1.79** (0.11)
Household Income (£1,000)	29.0 (9.1)	0.67** (0.11)
Ethnicity: White (%)	91.8 (12.4)	-0.39 (0.07)**
Ethnicity: Black (%)	2.7 (5.7)	0.06 (0.08)
Ethnicity: Asian (%)	5.6 (9.5)	0.33 (0.08)**
Smoker: Current or Ex (%)	53.5 (11.7)	-0.18 (0.15)
Nr of Children in the Household	1.1 (0.35)	-0.02** (0.01)
Lone Parent: Females (%)	12.8 (10.0)	0.08 (0.11)
GPs/Thousand Babies	52.2 (10.3)	1.53** (0.12)
GPs: Male (%)	65.6 (7.4)	-1.10** (0.08)
GPs: Age below 35 (%)	11.9 (3.4)	-0.22 (0.15)
GPs: Age 35 - 64 (%)	85.9 (3.6)	0.09 (0.16)
GPs: Age 65 and above (%)	2.2 (2.0)	0.13** (0.01)
Average Age of Adult Population	47.5 (3.4)	0.28** (0.08)

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... table 1 continued

Variable	**Aggregate Mean**	**Annual Trend**
	(Std. Dev. Across Area-Year Cells)	(Std. Err.)
Immigrants' Share of Population	8.7 (9.1)	0.26** (0.05)

Significance levels: ** : 1% * : 5% † : 10%.

Table 2: Linear Regression Models for the Uptake of the Combined Measles, Mumps and Rubella Vaccine.

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Year = 1998	-2.504	-1.799	-0.269	-0.024
	(0.252)**	(0.644)**	(1.101)	(1.033)
Year = 1999	-3.148	-1.700	-0.568	-0.667
	(0.334)**	(0.747)*	(1.082)	(1.082)
Year = 2000	-3.245	-1.660	0.083	-0.278
	(0.430)**	(0.920)†	(1.176)	(1.180)
Year = 2001	-6.656	-3.252	-1.990	-2.233
	(0.443)**	(0.922)**	(1.206)†	(1.185)†
Year = 2002	-8.912	-5.717	-3.353	-3.197
	(0.490)**	(0.893)**	(1.184)**	(1.250)*
Year = 2003	-10.790	-6.756	-2.862	-2.824
	(0.550)**	(1.123)**	(1.383)*	(1.495)†
Year = 2004	-9.838	-7.788	-6.939	-6.225
	(0.579)**	(1.216)**	(1.363)**	(1.559)**
Year = 2005	-6.912	-5.330	-4.571	-3.649
	(0.502)**	(1.156)**	(1.140)**	(1.275)**
Education (Age LFE $\geq$ 19)		8.848	7.214	6.044
		(2.903)**	(3.190)*	(2.867)*
Education $\times$ 1998		-3.195	-1.085	-0.730
		(2.433)	(2.897)	(2.559)
Education $\times$ 1999		-6.440	-4.893	-3.960
		(2.560)*	(3.139)	(2.989)
Education $\times$ 2000		-7.221	-4.729	-2.918
		(3.217)*	(3.318)	(3.152)
Education $\times$ 2001		-13.538	-11.624	-9.366
		(3.346)**	(3.713)**	(3.544)**

Continued on next page...

... table 2 continued

Variable	(1)	(2)	(3)	(4)
Education × 2002		-12.588	-9.304	-6.869
		(3.227)**	(3.614)*	(3.428)*
Education × 2003		-14.867	-8.626	-5.663
		(3.788)**	(4.239)*	(3.795)
Education × 2004		-8.847	-7.349	-5.928
		(4.084)*	(4.677)	(4.190)
Education × 2005		-7.548	-6.406	-5.663
		(3.711)*	(4.292)	(3.888)
Household Income (£1,000)			0.036	0.058
			(0.033)	(0.035)†
H-Hold Income × 1998			-0.075	-0.087
			(0.048)	(0.047)†
H-Hold Income × 1999			-0.055	-0.065
			(0.046)	(0.047)
H-Hold Income × 2000			-0.083	-0.096
			(0.035)*	(0.036)**
H-Hold Income × 2001			-0.061	-0.080
			(0.042)	(0.041)†
H-Hold Income × 2002			-0.108	-0.144
			(0.043)*	(0.044)**
H-Hold Income × 2003			-0.192	-0.224
			(0.049)**	(0.050)**
H-Hold Income × 2004			-0.043	-0.072
			(0.048)	(0.047)
H-Hold Income × 2005			-0.036	-0.057
			(0.041)	(0.039)
Ethnicity: Black				-4.654
				(2.496)†

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... table 2 continued

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Ethnicity: Asian				-0.008
				(1.154)
Smoker (Current or Ex)				-1.247
				(0.633)*
Nr Kids in H-Hold				0.275
				(0.231)
Lone Parent (Females)				-0.372
				(0.726)
GPs/1,000 Babies				0.042
				(0.025)†
GPs: Males				-0.003
				(0.067)
GPs: Age 35-64				0.112
				(0.071)
GPs: Age 65 or above				-0.306
				(0.192)
Average Age of Adults				-0.038
				(0.031)
Immigrant Share				-23.316
				(11.988)†
Area-Fixed-Effects	Yes	Yes	Yes	Yes
Number of Observations	852	852	852	852

Significance levels: $**$: 1% $*$: 5% $\dagger$: 10%.

Table 3: Linear Spline Models for the Uptake of the Combined Measles, Mumps and Rubella Vaccine.

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Subperiod 1 (1997-1998)	-2.537	-1.790	-0.365	-0.096
	(0.259)**	(0.623)**	(1.042)	(0.978)
Subperiod 2 (1998-2000)	-0.542	0.076	0.039	-0.263
	(0.180)**	(0.348)	(0.632)	(0.664)
Subperiod 3 (2000-2003)	-2.572	-1.960	-1.374	-1.207
	(0.129)**	(0.313)**	(0.495)**	(0.469)*
Subperiod 4 (2003-2005)	2.070	0.763	-0.750	-0.371
	(0.147)**	(0.417)†	(0.558)	(0.504)
Education (Age LFE $\geq$ 19)		12.432	8.708	7.260
		(4.877)*	(5.417)	(4.995)
Education $\times$ Subperiod 1		-3.387	-1.373	-1.048
		(2.312)	(2.786)	(2.520)
Education $\times$ Subperiod 2		-2.714	-2.789	-2.063
		(1.098)*	(1.176)*	(1.205)†
Education $\times$ Subperiod 3		-1.833	-0.897	-0.553
		(1.098)†	(1.119)	(1.018)
Education $\times$ Subperiod 4		3.918	1.853	0.673
		(1.337)**	(1.447)	(1.394)
Household Income (£1,000)	No	No	Yes	Yes
Other Area Characteristics	No	No	No	Yes
Area-Fixed-Effects	Yes	Yes	Yes	Yes
Number of Observations	852	852	852	852

Significance levels: $**$: 1% $*$: 5% $\dagger$: 10%.

Table 4: Linear Regression Models for the Uptake of Childhood Immunizations other than the MMR and of Cervical Screening Tests (”Smears”).

Variable	**Polio**	**Diph.**	**Hib.**	**Tetanus**	**Pert.**	**Smear**
Year = 1998	0.887	0.895	0.771	0.911	1.404	-1.385
	(0.688)	(0.679)	(0.670)	(0.681)	(0.689)*	(0.440)**
Year = 1999	0.361	0.343	0.489	0.407	0.954	-2.291
	(0.844)	(0.836)	(0.854)	(0.838)	(0.847)	(0.504)**
Year = 2000	1.028	1.028	0.947	1.047	1.852	-1.909
	(1.147)	(1.135)	(1.130)	(1.133)	(1.103)†	(0.402)**
Year = 2001	0.892	0.896	0.678	0.953	1.909	-0.417
	(0.958)	(0.951)	(0.985)	(0.959)	(0.972)*	(0.509)
Year = 2002	0.943	1.128	0.859	1.163	2.254	-1.292
	(1.394)	(1.376)	(1.365)	(1.388)	(1.363)†	(0.524)*
Year = 2003	0.871	0.861	0.659	0.829	2.285	-3.297
	(1.025)	(1.010)	(1.056)	(1.011)	(1.028)*	(0.809)**
Year = 2004	0.206	0.132	0.130	0.131	1.681	-1.508
	(1.114)	(1.103)	(1.128)	(1.107)	(1.097)	(0.752)*
Year = 2005	-0.192	-0.205	-0.346	-0.214	1.534	-0.992
	(1.259)	(1.231)	(1.341)	(1.226)	(1.246)	(0.895)
Education (Age LFE $\geq$ 19)	3.905	3.781	3.928	3.852	4.254	-2.794
	(1.787)*	(1.797)*	(1.755)*	(1.797)*	(1.787)*	(1.025)**
Education $\times$ 1998	0.994	1.245	0.990	1.213	1.087	1.852
	(2.345)	(2.378)	(2.378)	(2.361)	(2.256)	(1.540)
Education $\times$ 1999	-1.751	-1.777	-1.845	-1.787	-2.171	3.895
	(1.959)	(1.958)	(1.985)	(1.954)	(1.915)	(1.412)**
Education $\times$ 2000	-3.070	-3.035	-3.641	-3.125	-3.691	2.840
	(2.170)	(2.171)	(2.223)	(2.161)	(2.097)†	(1.159)*
Education $\times$ 2001	-3.886	-3.628	-4.277	-3.605	-3.667	3.112
	(2.285)†	(2.292)	(2.408)†	(2.292)	(2.318)	(1.243)*

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... table 4 continued

Variable	**Polio**	**Diph.**	**Hib.**	**Tetanus**	**Pert.**	**Smears**
Education × 2002	-4.794	-4.396	-4.672	-4.486	-4.762	3.059
	(2.323)*	(2.316)†	(2.388)†	(2.324)†	(2.314)*	(1.434)*
Education × 2003	-5.424	-5.466	-5.384	-5.654	-5.950	3.854
	(2.483)*	(2.422)*	(2.559)*	(2.436)*	(2.426)*	(1.355)**
Education × 2004	-5.345	-5.541	-5.374	-5.511	-5.964	1.846
	(2.433)*	(2.474)*	(2.340)*	(2.488)*	(2.485)*	(1.367)
Education × 2005	-5.686	-5.731	-6.001	-5.828	-6.269	3.430
	(2.449)*	(2.397)*	(2.430)*	(2.397)*	(2.378)**	(1.433)*
Household Income (£1,000)	0.010	0.012	0.004	0.013	0.022	0.007
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.016)
H-Hold Income × 1998	-0.053	-0.056	-0.047	-0.056	-0.063	0.020
	(0.030)†	(0.030)†	(0.031)	(0.031)†	(0.031)*	(0.020)
H-Hold Income × 1999	-0.029	-0.030	-0.032	-0.032	-0.034	0.006
	(0.028)	(0.028)	(0.029)	(0.028)	(0.029)	(0.023)
H-Hold Income × 2000	-0.056	-0.058	-0.046	-0.058	-0.062	-0.015
	(0.032)†	(0.031)†	(0.032)	(0.031)†	(0.031)*	(0.018)
H-Hold Income × 2001	-0.065	-0.068	-0.053	-0.072	-0.080	-0.011
	(0.028)*	(0.028)*	(0.028)†	(0.029)*	(0.030)**	(0.020)
H-Hold Income × 2002	-0.068	-0.074	-0.059	-0.076	-0.080	-0.021
	(0.050)	(0.050)	(0.050)	(0.051)	(0.050)	(0.019)
H-Hold Income × 2003	-0.046	-0.047	-0.034	-0.046	-0.057	0.013
	(0.032)	(0.031)	(0.034)	(0.031)	(0.032)†	(0.029)
H-Hold Income × 2004	-0.024	-0.020	-0.013	-0.022	-0.032	-0.001
	(0.033)	(0.032)	(0.032)	(0.032)	(0.032)	(0.022)
H-Hold Income × 2005	0.005	0.006	0.020	0.005	-0.007	-0.022
	(0.030)	(0.029)	(0.032)	(0.029)	(0.030)	(0.026)
Other Area Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Area-Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes

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... table 4 continued

Variable	**Polio**	**Diph.**	**Hib.**	**Tetanus**	**Pert.**	**Smears**
Number of Observations	852	852	852	852	852	852

Significance levels: $**$: 1% $*$: 5% $\dagger$: 10%.

Table 5: Descriptive Statistics for the Millennium Cohort Survey Sample. (Standard deviations not reported for binary variables.)

Variable	**Mean**	**St.Dev**	**Variable**	**Mean**	**St.Dev**
MMR Triple	0.884	-	Mother Married	0.668	-
Measles Single	0.053	-	Never Married	0.257	-
Mumps Single	0.029	-	Mother Separated	0.075	-
Rubella Single	0.049	-	Internet Access	0.669	-
Polio	0.976	-	Siblings = 0	0.251	-
Diphtheria	0.975	-	Siblings = 1	0.468	-
Tetanus	0.974	-	Siblings = 2	0.185	-
Pertussis	0.969	-	Siblings = 3	0.065	-
Hib	0.964	-	Siblings $\geq$ 4	0.030	-
Hib Extra	0.740	-	Subperiod 1	0.345	-
Mother's LFE at age $\geq$19	0.249	-	Subperiod 2	0.324	-
H-hold Eq. Inc.	0.667	0.541	Subperiod 3	0.331	-
Mother's Age	32.026	5.745	Not English at Home	0.158	-
Ethnicity: White	0.823	-	Mother Doesn't Smoke	0.726	-
Ethnicity: Asian	0.111	-	Mother Drinks 3+/week	0.178	-
Ethnicity: Black	0.044	-	Mother worked as "Scientist"	0.049	-
Ethnicity: Other	0.022	-	Mother worked in NHS	0.062	-
Private Childcare	0.121	-	No. Other Vacc $\leq$1	0.022	-
Gender (Male)	0.508	-	No. Other Vacc 2 - 5	0.023	-
Mother Catholic	0.094	-	No. Other Vacc = 6	0.233	-
Mother Muslim	0.090	-	No. Other Vacc = 7	0.722	-
Mother Voted Tory	0.107	-	Area: Good/Excellent	0.664	-
Asthma	0.118	-	See Grandmother Every Week	0.401	-
Long-Standing Illness	0.164	-			
Nr. Observations = 7,909					

Table 6: Probit Models for the Uptake of Childhood Immunizations in the Millennium Cohort Survey (Marginal Effects and Standard Errors).

Variable	**MMR**	**Polio**	**Diph.**	**Tet.**	**Pert.**	**Hib**	**Hib+**
Mother age FTE $\geq$ 19	-0.025	0.004	-0.001	0.003	-0.003	-0.008	-0.013
	(0.010)**	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.013)
Eq. H-hold Income (£10,000)	-0.022	0.006	0.007	0.001	0.011	0.012	-0.012
	(0.008)**	(0.004)	(0.004)†	(0.004)	(0.005)*	(0.005)*	(0.013)
Mother's Age	0.008	0.003	0.004	0.005	0.004	0.006	0.035
	(0.007)	(0.002)	(0.002)*	(0.002)**	(0.002)†	(0.003)*	(0.008)**
Mother's Age Sq./100	-0.018	-0.005	-0.007	-0.008	-0.007	-0.009	-0.047
	(0.010)†	(0.003)†	(0.003)*	(0.003)**	(0.004)*	(0.004)*	(0.013)**
Ethnicity: Asian	0.086	-0.005	0.000	-0.002	0.002	0.000	-0.006
	(0.019)**	(0.005)	(0.005)	(0.005)	(0.006)	(0.007)	(0.021)
Ethnicity: Black	0.093	0.008	0.005	-0.001	0.012	-0.007	-0.072
	(0.025)**	(0.007)	(0.007)	(0.007)	(0.009)	(0.010)	(0.028)*
Ethnicity: Other	0.012	0.002	-0.004	-0.001	-0.001	-0.006	-0.014
	(0.030)	(0.012)	(0.011)	(0.012)	(0.014)	(0.014)	(0.037)
Marital Stat.: Never Married	-0.017	-0.012	-0.013	-0.014	-0.016	-0.015	-0.065
	(0.011)	(0.003)**	(0.003)**	(0.004)**	(0.004)**	(0.005)**	(0.014)**
Marital Stat.: Prev. Married	-0.024	-0.009	-0.011	-0.013	-0.010	-0.011	-0.066
	(0.015)	(0.005)†	(0.005)*	(0.005)*	(0.006)†	(0.007)†	(0.020)**
Access to Internet	-0.020	0.005	0.005	0.005	0.003	0.008	0.009
	(0.010)†	(0.003)	(0.003)	(0.003)†	(0.004)	(0.004)†	(0.013)
Gender: Male	-0.017	-0.002	0.000	-0.001	-0.002	-0.002	-0.014
	(0.008)*	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.010)
Nr. Siblings = 1	0.028	0.001	0.000	0.002	0.003	-0.004	0.007
	(0.010)**	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.014)
Nr. Siblings = 2	0.038	0.000	0.003	0.003	0.002	-0.005	-0.048
	(0.013)**	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)	(0.017)**

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... table 6 continued

Variable	**MMR**	**Polio**	**Diph.**	**Tet.**	**Pert.**	**Hib**	**Hib+**
Nr. Siblings = 3	0.024	-0.004	-0.006	-0.005	-0.010	-0.014	-0.098
	(0.020)	(0.006)	(0.006)	(0.006)	(0.007)	(0.008)†	(0.024)**
Nr. Siblings $\geq$ 4	0.009	-0.018	-0.019	-0.020	-0.022	-0.032	-0.126
	(0.026)	(0.007)**	(0.007)*	(0.008)**	(0.009)*	(0.010)**	(0.033)**
Subperiod = 2	-0.018	0.004	0.006	0.007	0.011	0.018	0.020
	(0.010)†	(0.003)	(0.003)	(0.004)*	(0.004)**	(0.004)**	(0.013)
Subperiod = 3	-0.021	0.003	0.003	0.007	0.013	0.019	0.001
	(0.010)*	(0.003)	(0.003)	(0.004)†	(0.004)**	(0.004)**	(0.013)
Gov. Off. Reg.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	7,909	7,909	7,909	7,909	7,909	7,909	7,909

Significance levels: $**$: 1% $*$: 5% $\dagger$: 10%.

Table 7: Probit Models for the Uptake of the MMR the Millennium Cohort Survey. Alternative Specifications (Marginal Effects and Standard Errors).

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Mother age left FTE $\geq$ 19	-0.031		-0.028	-0.022	-0.022	-0.022
	(0.009)**		(0.010)**	(0.010)*	(0.009)*	(0.009)*
Eq. H-hold Income (£10,000)		-0.028	-0.022	-0.022	-0.023	-0.020
		(0.008)**	(0.009)**	(0.009)**	(0.008)**	(0.008)*
Additional Covariates	No	No	Yes	No	No	Yes
Maternal Risk Behavior	No	No	No	Yes	No	Yes
Previous Vaccines	No	No	No	No	Yes	Yes
Gov. Off. Reg.	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	7,909	7,909	7,909	7,909	7,909	7,909

Significance levels: $**$: 1% $*$: 5% † : 10%.

Table 8: Probit Models for the Uptake of Single Measles, Mumps and Rubella Vaccines in the Millennium Cohort Survey (Marginal Effects and Standard Errors).

Variable	**Some single jab**	**Some single jab given MMR rejection**	**Three single jabs given some single**
Mother age left FTE $\geq$ 19	0.008	-0.054	-0.100
	(0.006)	(0.046)	(0.056)†
Eq. H-hold Income (£10,000)	0.022	0.136	0.079
	(0.005)**	(0.042)**	(0.042)†
Demographics	Yes	Yes	Yes
Subperiods	Yes	Yes	Yes
Gov. Off. Reg.	Yes	Yes	Yes
Number of Observations	7,669	889	432

Significance levels: $**$: 1% $*$: 5% † : 10%.

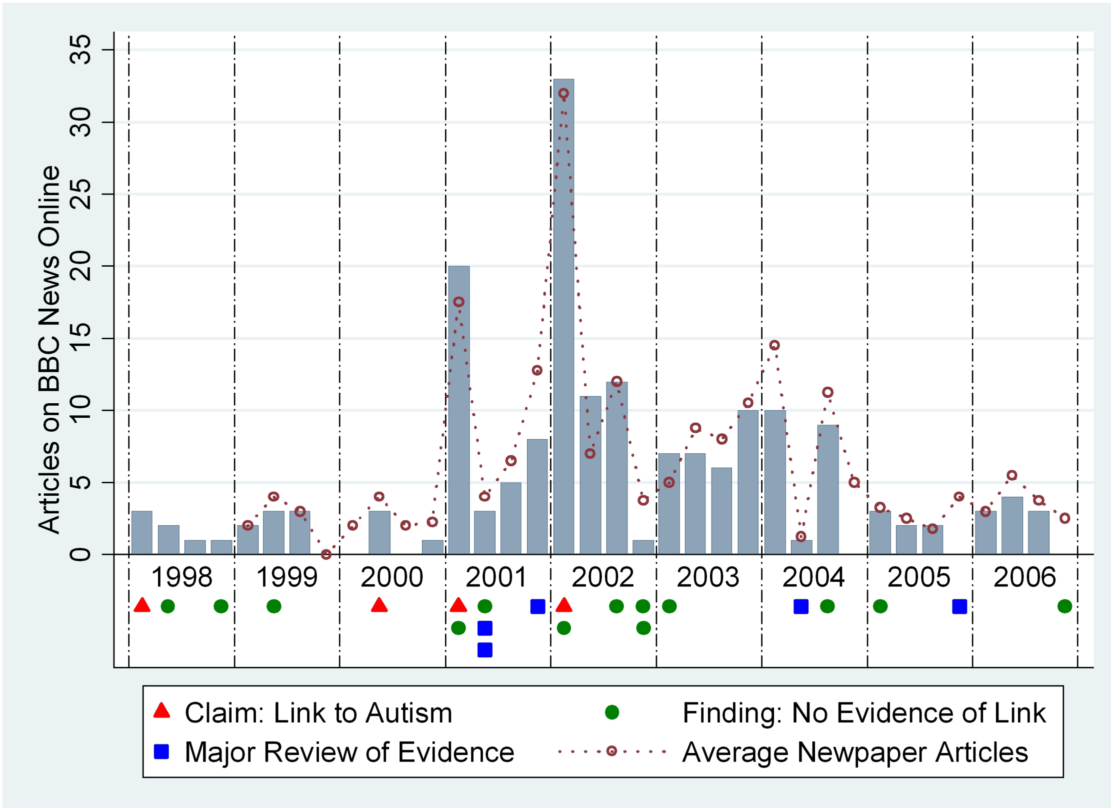

Figure 1: A timeline indicating the number of articles relating to the controversy appearing in BBC news online and in four main newspapers, as well as the timing of the publications of the main relevant pieces of research.

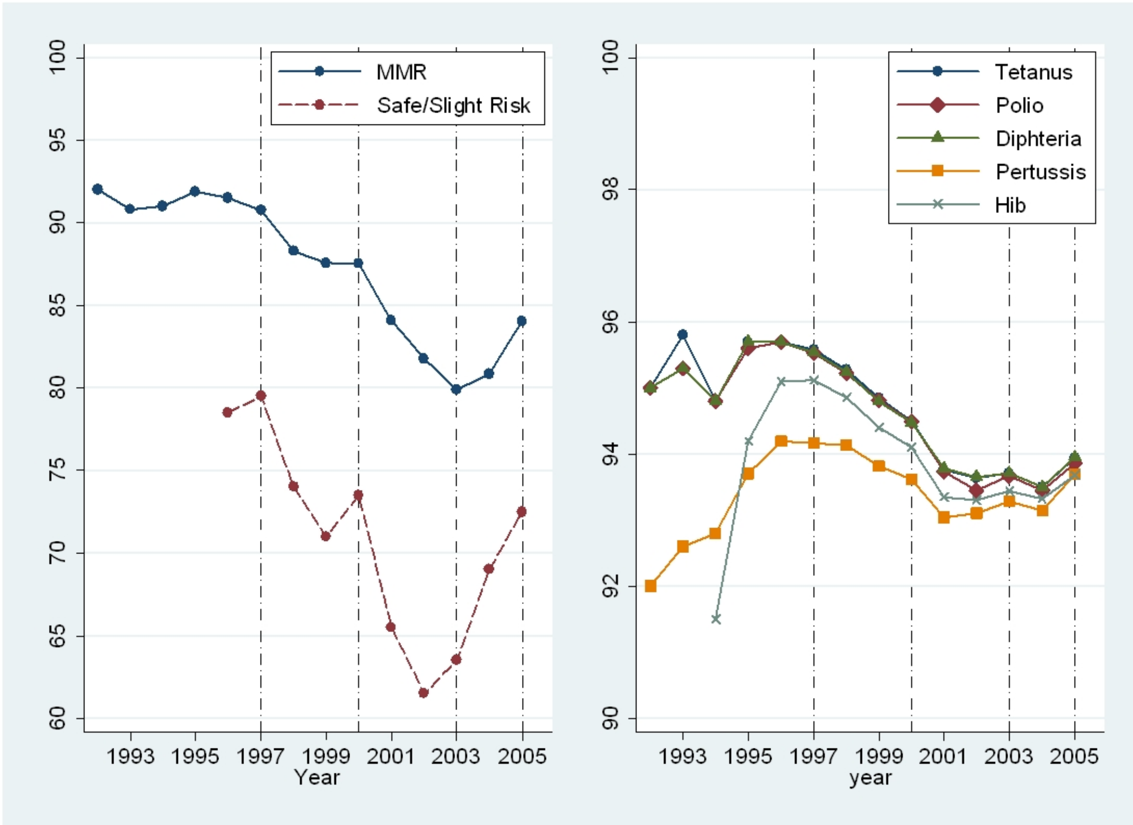

Figure 2: Trends in the uptake of immunizations; data for children who reach their second birthday and the proportion of mothers with young children who perceive the MMR vaccine to be either "completely safe" or pose a "slight risk". (Source: Smith et al., 2007).

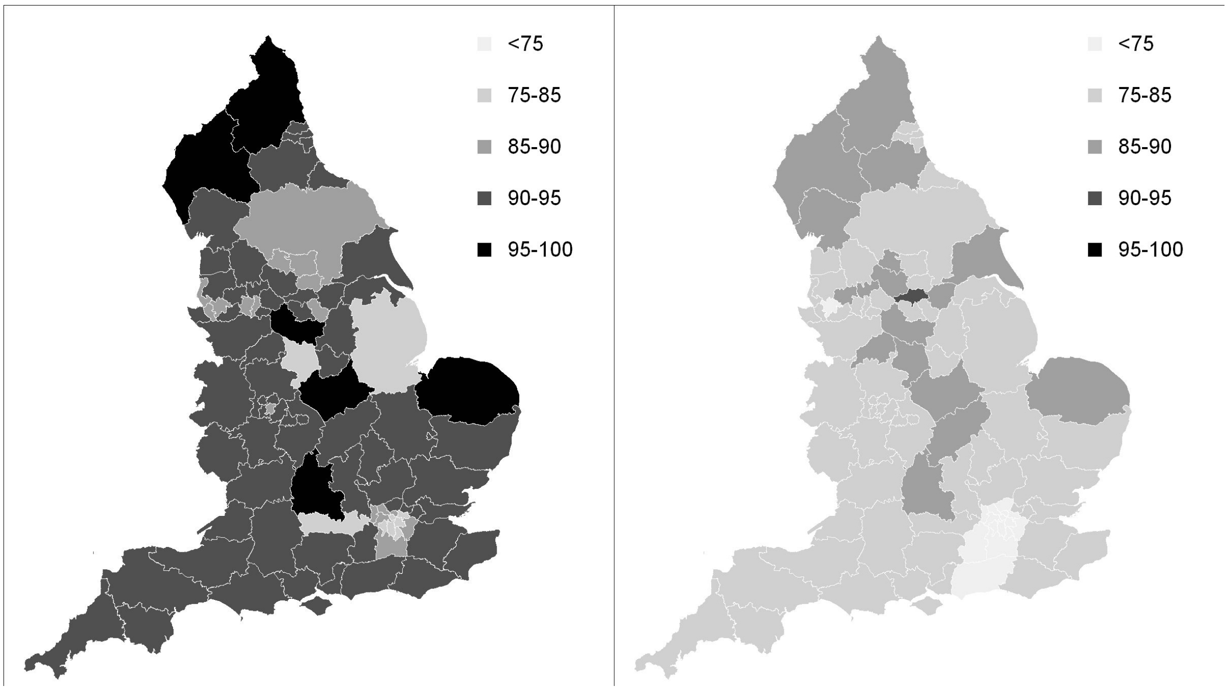

Figure 3: The MMR uptake rate in 1997 and 2003 across Health Authorities for children who reached their second birthdays.