CENTRE for ECONOMIC PERFORMANCE

CEP Discussion Paper No 929

May 2009

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

Dan Anderberg, Arnaud Chevalier
and Jonathan Wadsworth

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Abstract
One theory for why there is an education gradient in health outcomes is that more educated individuals more quickly absorb new health-related information. The measles, mumps, and rubella (MMR) controversy provides a case where, for a short period, some publicized research suggested that the particular childhood vaccine could have serious side-effects. As the controversy unfolded, uptake of the vaccine by more educated parents decreased relative to that of less educated parents, turning a positive education gradient into a negative one. We also consider the response in terms of uptake of other childhood vaccines and purchases of alternatives to the MMR.

Keywords: Childhood vaccinations, health outcomes, education
JEL Classifications: H42, I18

This paper was produced as part of the Centre's Labour Markets Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

Acknowledgements
The authors would like to thank NatCen for providing additional data from the Health Survey for England. We also thank Jerome Adda, Amanda Gosling, and seminar participants at the Tinbergen Institute, Kent, Rouen, Maynooth, Royal Holloway, IFS, Bristol, Bologna, St. Andrews, CEP, SOLE, and NBER for numerous helpful comments.

Dan Anderberg is a Professor in the Department of Economics, Royal Holloway College. Arnaud Chevalier is an Associate of the Education and Skills Programme, Centre for Economic Performance, London School of Economics. He is also a Senior Lecturer, Department of Economics, Royal Holloway College. Jonathan Wadsworth is a Senior Research Fellow with the Labour Markets Programme, CEP and Professor in the Department of Economics, Royal Holloway College.

Published by
Centre for Economic Performance
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

ISBN 978-0-85328-382-9

I Introduction

In February 1998 a paper was published in the highly respected British medical journal *The Lancet*. The article reported on twelve children, referred to the Royal Free Hospital in London, with developmental disorders and a set of bowel symptoms, and suggested a link between autism and the particular gastrointestinal pathologies. While the paper did not claim to have proven any link between the syndromes and the measles, mumps and rubella (MMR) vaccine, the parents of eight of the twelve children blamed the combined vaccine, saying that the symptoms had set in days after receiving the immunization. In the press conference before the publication and in a video release issued to broadcasters 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. While the government consistently tried to reassure the public about the safety of the vaccine, confidence in the multi-component vaccine declined (see below). Following the initial publication and subsequent coverage by the media, the uptake of the MMR also declined sharply, dropping by over ten percentage points in five years, before eventually picking up again. However, by 2003, a substantial body of research had failed to verify any link between the MMR and autism and the emerging consensus among researchers was that the vaccine was safe to use.

The case of the MMR controversy provides an interesting case where, for a relatively short period of time, some research, publicized in the media, suggested a potential risk of serious side-effects associated with a standard medical procedure and where there was a sharp behavioral response. We consider the controversy from the perspective of health inequalities and the diffusion of information on advances in medical knowledge.

A large literature has documented the positive link between individuals' education and their health outcomes.[1] Indeed, a small number of recent studies, mainly using school leaving age reforms as instruments, have found evidence of a causal link running from education to health. One of the hypotheses to receive recent attention in the economics literature is that more edu-

[1] A literature review is provided in the next section

cated individuals have better understanding of, and more quickly absorb, advances in medicine. The ideal setting to study this hypothesis empirically is situations where new health related information becomes available.

We thus consider whether and how the reaction to the controversy, in terms of vaccine uptake behavior, differed among groups of parents with different levels of education and income. The case of the MMR controversy provides a useful case for studying individuals' behavioral responses to new information for several reasons. First, a set of childhood vaccines are provided free of charge through the National Health Service (NHS); hence parents can either accept or reject them at no monetary cost.[2] Second, the controversy took place over a relatively short period and the response was strong; moreover, the fact that the initial information was subsequently overturned and the decline in uptake ceased gives us confidence that our results are not driven by other unrelated trends. Finally, the information coming from different sources regarding the safety of the MMR vaccine was, at times, contradictory. Experimental evidence (Viscusi, 1997) suggests that individuals may give undue weight to high risk information while low risk information, especially when provided by the government, is underweighted.

For our main analysis we use data on the uptake of the MMR, and other childhood immunizations, at the Health Authority area level for the years 1997 to 2005, which we combine with corresponding data on the characteristics of the local populations obtained from the Health Survey for England (HSE). We find that the uptake rate of the MMR among parents who stayed on in education past the age of 18 declined by around ten percentage points more than that for less educated parents over the period 1998 to 2003. Most of the relative decline in uptake also appear to have occurred during the early stages of the controversy when media attention was relatively low. We also find, however, that the same group of parents reduced their relative uptake of other "uncontroversial" childhood immunizations, 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

[2]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.

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. Analysis of this data allows us to confirm that there was, at the peak of the controversy, a negative education gradient in the uptake of the MMR after controlling for a range of other potentially confounding individual characteristics. Among 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. The MCS also allows us to explore which parents purchased alternatives to the MMR, in the form of single vaccines, in the private market.

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

Two theoretical models are often invoked to explain why there may be a causal effect of education on health outcomes. The production efficiency hypothesis (Becker, 1965) states that human capital is effectively a factor of production that allows the individual to obtain a better outcome given a set of inputs. This would imply that more educated individuals would demand fewer inputs into health production while still enjoying better health (Grossman, 2000). Indeed, much of the literature associated with the production efficiency hypothesis is concerned with estimating the demand for health inputs and in particular its relation to education. In contrast, the allocative efficiency hypothesis argues that human capital is not a primary input into health production — it is simply something that allows individuals to make better choices of input mixes (Rosenzweig and Schultz, 1982). A few existing empirical tests of the allocative efficiency hypothesis examine whether the more educated are quicker to absorb information about risks or new medical technologies.[3] 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. In contrast, Goldman and Smith (2005), focusing on hypertension drugs, find no effect of education on the adoption of new medical technologies.

The identification strategy to testing the allocative efficiency hypothesis in our paper concerns the reaction by different groups to information under uncertainty.[4] It is thus 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. Both studies find that more educated individuals reacted quicker to new information regarding risk. One extra dimension in our case is that the risk information was "reversed" within a relatively short period of time. This means that the reaction patterns that we observe are unlikely to reflect long-run trends.

Any study of the links between education and several health outcomes (see Grossman (2006) or Cutler and Lleras-Muney (2008) for recent surveys) has to deal with the issue that any realized correlations between education and health may originate from three sources: i) a causal effect of education on health, ii) a common factor explaining both the education and health investment decisions (Fuchs, 1982), iii) reverse causality, where bad health as a child would prevent educational investment (Case et al., 2005). Several studies have attempted to estimate the causal effect of education by relying on natural experiments; see among others Arendt (2005) for Denmark, Lleras-Muney (2005) and Mazumder (2006) for the US, and Clark and Royer (2007) for the UK. While the general view, expressed in the reviews of Grossman (2006) and Cutler and Lleras-Muney (2008), is that there is a causal effect of education on health, the accumulated evidence is mixed. Clark and Royer (2007) and Mazumder (2006) for example find no significant impact of education. Moreover, instrumental variable methods often only identify

[3] Innovation in health technology could lead to a temporary increase in health inequality (Victora et al., 2000, Glied and Lleras-Muney, 2008).

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

local average treatment effects, as typically the policy changes identifying the effect of education affect only a specific population. As an alternative, Lundborg (2008) uses a representative sample of monozygotic twins and a between-twin fixed effect model to control for genetic and family characteristics, finding that compared to high school dropouts, other individuals have a higher level of self-reported health and fewer chronic health conditions. Regarding the intergenerational effect of education and health, Currie and Moretti (2003), Chou et al. (2007), and Chevalier and O'Sullivan (2008) all report positive effects of maternal education on birth weight, in contrast to the findings of Lindeboom et al. (2006).

A handful of papers in other disciplines have analyzed the determinants of the decision to immunize children with the MMR vaccine, using datasets similar to ours. Middleton and Baker (2003) use Health Authority (HA) data on MMR vaccination at age 2 over an earlier period 1991-2001 and report that MMR coverage fell faster in more affluent areas. However they make no attempt to control for area fixed effects or time varying confounding characteristics of the HA. Wright and Polack (2005) use the same dataset to estimate the determinants of vaccinations in 1997 and 2003. They use the 2001 census to map local area level information on deprivation and education and estimate that between these two years, areas with a greater share of the population with no qualifications experienced less of a decrease in the MMR vaccination rate. Pearce et al. (2008) use the MCS and report that failure to immunize is greater among children with more educated mothers and among higher household incomes. However, they do not account for many observable characteristics of the mother that may explain this correlation. In short, while these papers find that more education and less deprivation are associated with a reduction in the propensity to vaccinate with the MMR after the information on the potential side-effect became available, they do not provide enough evidence that these associations are not due to other characteristics.

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 favour and against MMR, we only measure the intensity of the reporting. Media coverage was particularly intense from spring 2001 through 2004.

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 (together with a colleague) 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. The authors found no evidence of any discontinuity in the incidence of autism nor a change in the trend around the introduction of the MMR in 1988, no evidence of any differences in age of diagnosis between vaccinated and unvaccinated children, and no evidence for any clustering in onset in the months after vaccination. Another research design compared the incidence of gastrointestinal disorders in children with autism (prior to their diagnosis) to children without autism and found no differences . Other studies look for discontinuities in the incidence of autism in "natural experiments" settings: e.g. Gillberg and Heijbel (1998) find no difference in incidence of autism among those born before and after the introduction of the MMR vaccine in Sweden in 1982, while Honda et al. (2005) consider the "reverse" experiment in Japan where, for reasons unrelated to autism and bowel disease, the MMR vaccine was withdrawn in 1993, and find no evidence that this reduced the upward trend in diagnosed cases of autism. Virological studies have similarly found no evidence of persistent measles infection in autistic children (D'Souza et al., 2006). 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).[5]

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.

[5]The list of main studies rejecting a causal link was compiled from the summaries of the research provided by the NHS and the BBC.

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 (84.2%); other information sources were newspapers or magazines (18.1%), books or journals (12.3%), a nurse (8.2%), a health clinic (7.5%), friends or family members (7.3%), and the internet (7.0%). In the UK, Pareek and Pattison (2000) studied sources of information in the particular context of the MMR using a cross-sectional survey of 295 mothers in Birmingham. 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 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 and timing of media coverage as part of the general timeline. To this end, we collected time-series statistics on the coverage of the controversy from the online editions of BBC news and four major daily newspapers (the Guardian, the Independent, the Daily Mail, and the Telegraph).[6] For each source we collected, through the internet, all articles relating to the controversy. 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.

[6]The above data 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), but also since it raises issues about how to model dynamic responses.

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. 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.

In order to verify that the amount of coverage by the BBC is representative, figure 1 also shows the average number of newspaper articles relating to the controversy from 1999 onwards. The volume and timing of coverage is clearly very similar to that of the BBC, again showing how media coverage was relatively low until the first quarter of 2001.

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 Organisations (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.[7]

The childhood immunization schedule for children 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.[8] All these vaccines are provided free of charge through the NHS. In

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

[8] Between the ages of three and five years, there are boosters of all the above except the hib. We focus on the

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).[9]

The data on area-level uptake rates, available through the NHS Information Centre, is collected by the Health Protection Agency through the Cover of Vaccination Evaluated Rapidly (COVER) data collection programme. The COVER system receives data from the health administration units (the HAs until 2002 and the PCOs thereafter). The programme collects information 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; 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.[10]

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.

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

uptake of the primary courses and hence do not consider the boosters. A particular hib booster known as "hib extra" was introduced after routine monitoring revealed that the number of cases of hib had gone up in 2001 and 2002. It is given to all children between the age of six months and four years. We consider the "hib extra" in the analysis of the cohort survey data below. In November 1999 a further vaccine against meningitis C was introduced; since uptake data is only available from 2000 onwards we do not consider this vaccine.

[9] 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).

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

that identifies household area information in terms of the administrative health geography.[11] 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. In characterizing the adult populations of parenting age, we include all adults aged 16-55 in the HSE's general population sample. In order to capture the characteristics of the population that are most likely to be parents to young children, we give each observed adult a weight that depend on his/her age, where the weight is the value of an empirical density function of age among parents to newborn babies.[12] 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.[13]

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.[14] 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 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

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

[12]The alternative of using only observed parents would have reduced the already relatively small average cell size by about 50 percent. The frequency distribution of age among parents to newborn children is obtained from the Millennium Cohort Survey which is described below.

[13]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.

[14]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. We also tried other threshold values but found that the chosen value provided the best fit; this was is also corroborated for the MCS below.

of children per household, the fraction of females that are lone parents, and the fraction of adults that ever smoked (since smokers may have different health risk attitudes).

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. 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).[15] Finally, male and female GPs may advice parents differently we control for the gender composition of the local GP population.[16] 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 decade. 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.

[15] Note e.g. that there was an earlier scare relating to the pertussis vaccine that took place in the mid- to late 1970s which the GPs in the youngest age group will not have had any experience with. Conversely, GPs above retirement age will have been trained before the introduction of many of the currently used vaccines and may have a different attitude to routine vaccination.

[16] 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.[17] 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.

---

[17] 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 there were different responses to the MMR controversy for parents with different levels of education in terms of uptake of the freely provided combined vaccine. 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:

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

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.[18]

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 education and household income affected the time 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

[18] Since the model includes area- and year fixed-effects the α-coefficients are identified from the fact that the change over time in educational attainment, income, ethnicity, smokers, number of children in households, proportion of lone parents, number of GPs, and average age of adults, has not been uniform across areas.

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 by parents who left education before age 19. The coefficients on the interactions between education and the year dummies measure the *additional* response across time for parents who did stay on in full time education until age 19 or higher. Hence, adding the coefficients for any one year gives the change in uptake, relative to the base year 1997, for parents with high education. E.g. for 1998, the uptake rate by highly educated parents was five $(1.799 + 3.195)$ percentage points lower than in the base year 1997.

These results suggest that parents with low education responded relatively less to the MMR controversy, both in its initial phase and at its peak. E.g. for the years 1999 to 2001, the reduction in uptake by low educated parents is about half of the observed aggregate reduction in uptake; when the uptake by low educated parents reached its lowest point it was only about 8 percentage points lower than their 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 behaviour, including its indirect effect via higher income, the third specification separates out the income effect from the education effect. The effect of education, in this latter specification, is hence that which obtains net of income. Controlling for income generally reduces the estimated low-educated parents' response, particularly for the years 1998 to 2000. Indeed, for this group and these years, the estimated response is effectively zero; only from 2002 onwards do we estimate responses for low educated parents that are sizeable and statistically significant. In contrast, the estimated additional responses by high educated parents remain negative and sizeable from 1999 onwards and statistically significant for the years around the height of the controversy. Controlling for income reduces the estimated downward trends in uptake for both educational categories but does not overturn the general pattern of larger responses by high educated parents.

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 income distribution 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, especially aged 35-64, and, possibly, a lower uptake among blacks and smokers; however the coefficients are only significant at the 10 percent level.[19] Based on this, most general, specification we would conclude that a six

[19]The uptake response to the controversy could potentially be related to local infection risk. To explore this we estimated a further 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 and the point estimates were positive. This is the opposite of what would be expected if part of the decline in uptake was due to initial high immunity rates. Furthermore, adding these controls, did not alter much the estimated differential response by high and low educated parents. A second concern was that the relatively small cell sizes used to determine the demographic variables could potentially introduce measurement errors; hence we also experimented with specifications where we replaced the annual values of the variables with their moving

percentage point *positive* education gradient that existed prior to the controvery had, by 2001 to 2003, been eliminated and turned to a one to three percentage point *negative* education gradient.

The estimates suggest that the decrease in relative uptake of the MMR by high educated parents 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 decline in uptake among lower educated parents was more or less on par with that for high educated parents. 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. Finally, 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 by low educated parents. Similarly, the coefficient on the interactions between education and a given subperiod measures the additional annual change in uptake by highly educated parents. In the spline specification, again, there is no evidence of any trend in uptake of the MMR prior to 1998, neither among parents with low education, nor among parents with high education. We see no significant response by low educated parents until after 2000 (i.e. the first significant response occurs in the third subperiod); in contrast, for high educated parents we see a sharp significant decline in the second subperiod, i.e. from 1998 onwards. Moreover, in the third and fourth subperiods there are no statistically significant differences in trends across the two

averages. This had little impact on the estimates.

educational groups.[20] In line the results from Table 2, the results from the spline specification 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.[21]

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

[20] Two previous studies, mentioned above, 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", "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.

[21] 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 predicted dynamic response 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 negligable impacts on the estimated effects of education. Results can be obtained from the authors upon request.

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 MMR, possibly with an extra lag of one year due to the nature of the data collection process,[22] (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 the high education group. For the low education parents there are generally speaking no statistically significant changes in behavior, 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 for either low- or high educated parents 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 by parents. Second, the decline in relative uptake by high educated individuals 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

[22] 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.

("smear tests").[23] Smear tests provide a suitable comparison in that women 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. Women aged 25 to 65 are invited for screening every three to five years and the dependent variable used in the regression measures the number of women screened within the year as a fraction of the eligible population. The regression 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 the high education group, 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.[24] 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.

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.

[23] We would like to thank Amanda Gosling for the suggestion to look at the uptake of smear tests.

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

The Millennium Cohort Survey Data

Since our earlier analysis pertained to English HAs we use all MCS children born in England.[25] 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 Table 5.[26,27]

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

[26] 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 immunisations is generally unequally socially distributed (Suarez, Simpson, and Smith, 1997).

[27] 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.

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. 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.[28] 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 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 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.

[28] 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).

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.[29]

The Option of Single Vaccines

So far we have focused on takeup of the MMR as the relevant outcome. However, 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 have argued above that the significant negative income effect on MMR uptake is likely to be, at least in part, driven by the single vaccines option. For the other vaccines, for which there were no alternatives available in the market, we saw income effects that were either negative but not significant (in the NHS data) or positive and, in some cases, significant (in MCS).

The Medicines and Health Care Products Regulatory Agency (MHRA) is responsible for

[29] 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, indicating a threshold effect qualifications that are typically obtained at the age of 18 or above.

issuing licenses for the manufacture and importation of drugs/vaccines in the UK. No single measles, mumps or rubella vaccines are licensed for either manufacture or general sale in the UK. Nevertheless, certain brands of single antigen 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, however, 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. More or less any parent choosing some single jab opts for the measles vaccine and also the rubella; however, nearly half choose not to take the mumps (which is generally perceived to be a less dangerous disease).

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

Immunization is a proven tool for controlling and even eradicating disease, sparing people from suffering, disability, and death. The World Health Organization estimate that in 2002 immunization averted about two million deaths. 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.[30] We hence hypothesized that the decline of the MMR uptake rate should have been more pronounced among high educated parents.[31] We found that this was indeed the case: our findings 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

[30]The idea that individuals with more education are faster to adopt new technologies is certainly not a novel one. In his pioneering book "Diffusion of Innovation" Everett Rogers (2003, originally published in 1962), building on the earlier work by Ryan and Gross (1943) on the diffusion of hybrid seed corn in Iowa, identified different types of adopters in the diffusion process – "innovators", "early adopters", "early majority", "late majority", and "laggards" – and noted that the first two types are often more educated.

[31]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.

low educated parents. In fact, the relative decline in uptake for the high educated parents was 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.[32]

A differential response by high- and low educated parents can have obtained through several different channels: (1) more educated parents may have followed the news more closely; (ii) they may have had a better understanding of what was being reported; (iii) they may have been given different advice from their GPs; (iv) they may have absorbed and understood the information equally but simply reacted differently. Consider these theories in turn. The MMR controversy was reported in the national news from the very first day the story broke; given that access to television is nearly universal everyone would, in principal, have had access to the information.[33] Equal access, however, does not imply that individuals follow the news with equal intensity; hence using the current data we cannot discriminate between the first and the second channel. The third channel 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 fourth channel would require parents to differ in some other characteristic, correlated with education, that could induce differential responses. A prime candidate would be risk-attitudes; however, we consider this unlikely to be the main explanation for several reasons. For one, there is no concensus in the empirical literature that education is positively correlated with risk-aversion (see e.g. Harrison et al., 2007

[32]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 that part of this reversal in the fertility trend may be attributed to changes in tax-benefit policy and show that, consistent with that hypothesis, the increase in fertility was stronger among females with low education and income. Similarly, using the current data to perform an area-level analysis of the change in the number of births suggests that, for low educated adults, fertility declined until 2001 and increased thereafter, while for high educated adults fertility was essentially flat over the whole period 1997 to 2005.

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

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 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.[34] 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 underweighted.[35] 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 here".

[34] 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."

[35] Mistrust in governmental health messages in the UK may also have been increased by the handling of the information of the risk associated with the "Mad Cow" diseases in the mid-Nineties and the allegation of cover up by the government (Bartlett, 1998). See Adda (2007) for an analysis of behavioral responses (in France) to the Mad Cow crisis.

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. The government's policy throughout the controversy was to reassure the public about the safety of the MMR, and this may well have been the best policy given the circumstances. Nevertheless, 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 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.

References

Adda, J. (2007), 'Behavior towards health risks: an empirical study using the "mad cow" crisis as an experiment', *Journal of Risk and Uncertainty* **35**, 285–305.

Arendt, J. N. (2005), 'Does education cause better health? a panel data analysis using school reform for identification', *Economics of Education Review* **24**, 149–160.

Bartlett, D. (1998), 'Mad cows and democratic governance: BSE and the construction of a free market in the UK', *Crime, Law and Social Change* **30**, 237–257.

Becker, G. S. (1965), 'A theory of the allocation of time', *Economic Journal* pp. 493–517.

Black, C., Kaye, J. A. & Jick, H. (2002), 'Relation of childhood gastrointestinal disorders to autism: nested case-control study using data from the UK general practice research database', *British Medical Journal* **325**, 419–421.

Blinder, A. & Krueger, A. (2004), 'What does the public know about economic policy, and how does it know it?', *Brookings Papers on Economic Activity* **1**, 327–87.

Brewer, M., Ratcliffe, A. & Smith, S. (2007), 'Does welfare reform affect fertility? evidence from the UK', University of Bristol, CMPO Working Paper Series No. 07/177.

Cameron, J. C., Friederichs, V. & Robertson, C. (2007), 'Vaccine uptake: new tools for investigating changes in age distribution and predicting final values', *Vaccine* **25**, 6078–6085.

Chevalier, A. & O'Sullivan, V. (2008), 'Mother's education and birth weight', Royal Holloway University of London (mimeo).

Chou, S. Y., Liu, J. T., Grossman, M. & Joyce, T. (2007), 'Parental education and child health: evidence from a natural experiment in Taiwan', Working paper no. 13466, National Bureau of Economic Research.

Clark, D. & Royer, H. (2007), 'The effect of education on adult mortality and health: evidence from the United Kingdom', University of Florida (mimeo).

Currie, J. & Moretti, E. (2003), 'Mother's education and the intergenerational transmission of human capital: evidence from college openings', *Quarterly Journal of Economics* **118**(4), 1495–1532.

Cutler, D. & Lleras-Muney, A. (2008), Education and health: evaluating theories and evidence, *in* J. House, R. Schoeni, G. Kaplan & H. Pollack, eds, 'The effect of social and economic policy on health', Russell Sage Press.

de Walque, D. (2004), 'Education, information, and smoking decisions: evidence from smoking histories, 1940-2000', Working paper no. 3362, World Bank, Washington, DC.

de Walque, D. (2007), 'How does the impact of an HIV/AIDS information campaign vary with educational attainment? evidence from rural Uganda', *Journal of Economic Development* **84**, 686–714.

Demicheli, V., Jefferson, T., Rivetti, A. & Price, D. (2005), 'Vaccines for measles, mumps and rubella in children', *The Cochrane Database of Systematic Reviews* . Art. No.: CD004407.

Donald, A. & Muthu, V. (2002), 'Measles', *BMJ Clinical Evidence* (7), 331–40.

D'Souza, Y., Fombonne, E. & Ward, B. J. (2006), 'No evidence of persisting measles virus in peripheral blood mononuclear cells from children with autism spectrum disorder', *Pediatrics* **118**, 1664 – 1675.

Farrington, C. P., Miller, E. & Taylor, B. (2001), 'MMR and autism: further evidence against a causal association', *Vaccine* **19**, 3632–3635.

Fuchs, V. R. (n.d.), Time preference and health: an exploratory study, *in* V. R. Fuchs, ed., 'Economic Aspects of Health', University of Chicago Press, Chicago.

Gellin, B. G., Maibach, E. W. & Marcuse, E. K. (2000), 'Do parents understand immunizations? a national telephone survey', *Pediatrics* **106**, 097–1102.

Gillberg, C. & Heijbel, H. (1998), 'MMR and autism', *Autism, The International Journal of Research and Practice* **2**, 423–424.

Glied, S. & Lleras-Muney, A. (2008), 'Technological innovation and inequality in health', *Demography* . Forthcoming.

Goldman, D. & Smith, J. (2005), 'Socioeconomic differences in the adoption of new technologies', Working paper no. 12218, National Bureau of Economic Research.

Grossman, M. (2000), The human capital model, *in* A. J. Culyer & J. P. Newhouse, eds, 'Handbook of Health Economics', Vol. 1A, Elsevier, Amsterdam.

Grossman, M. (2006), Education and nonmarket outcomes, *in* E. Hanushek & F. Welch, eds, 'Handbook of the Economics of Education', North-Holland, Amsterdam.

Halsey, N. A., Hyman, S. L. & the Conference Writing Panel (2001), 'Measles-mumps-rubella vaccine and autistic spectrum disorder: report from the new challenges in childhood immunizations conference convened in Oak Brook, Illinois, June 12-13, 2000', *Pediatrics* **107**.

Harrison, G., Lau, M., E & Rustrom (2007), 'Estimating risk attitudes in Denmark: a field experiment', *Scandinavian Journal of Economics* **109**(2), 341–368.

Honda, H., Shimizu, Y. & Rutter, M. (2005), 'No effect of MMR withdrawal on the incidence of autism: a total population study', *Journal of Child Psychology and Psychiatry* **46**, 572–579.

Institute of Medicine (2001), 'Immunization safety review: measles-mumps-rubella vaccine and autism', National Academies Press, Washington D.C.

Institute of Medicine (2004), 'Immunization safety review: vaccines and autism', National Academies Press, Washington D.C.

Kaye, J. A., del Mar Melero-Montes, M. & Jick, H. (2001), 'Mumps, measles, and rubella vaccine and the incidence of autism recorded by general practitioners: a time trend analysis', *British Medical Journal* **322**, 460–463.

Lindeboom, M., Llena-Nozal, A. & van der Klaauw, B. (2006), 'Parental education and child health: evidence from a schooling reform', Working paper no. 2516, IZA, Bonn.

Lleras-Muney, A. (2005), 'The relationship between education and adult mortality in the United States', *Review of Economic Studies* **72**, 189–221.

Lleras-Muney, A. & Lichtenberg, F. R. (2002), 'The effect of education on medical technology adoption: are the more educated more likely to use new drugs?', Working paper no. 9185, National Bureau of Economic Research.

Lundborg, P. (2008), 'The health returns to education: what can we learn from twins', Working paper no. 3399, IZA, Bonn.

Madsen, K. M., Hviid, A., Vestergaard, M., Schendel, D., Wohlfahrt, J., Thorsen, P., Olsen, J. & Melbye, M. (2002), 'A population-based study of measles, mumps, and rubella vaccination and autism', *The New England Journal of Medicine* **347**, 1477–1482.

Mazumder, B. (2006), 'How did schooling laws improve long-term health and lower mortality', Working paper no. 2006-23, Federal Reserve Bank of Chicago.

Medical Research Council (2001), 'MRC review of autism research', Report, MRC.

Middleton, E. & Baker, D. (2003), 'Comparison of social distribution of immunisation with measles, mumps, and rubella vaccine, England, 1991-2001', *British Medical Journal* **326**, 854.

Miller, E., Andrews, N., Waight, P. & Taylor, B. (2003), 'Bacterial infections, immune overload, and MMR vaccine', *Archives of Disease in Childhood* **88**, 222–223.

Pareek, M. & Pattison, H. (2000), 'The two-dose measles, mumps, and rubella (MMR) immunisation schedule: factors affecting maternal intention to vaccinate', *British Journal of General Practice* **50**, 969–971.

Pearce, A., Law, C., Elliman, D., Cole, T. & Bedford, H. (2008), 'Factors associated with uptake of measles, mumps, and rubella vaccine (MMR) and use of single antigen vaccines in a contemporary UK cohort: prospective cohort study', *British Medical Journal* . Forthcoming.

Peltola, H., Patja, A., Leinikki, P., Valle, M., Davidkin, I. & Paunio, M. (1998), 'No evidence for measles, mumps and rubella vaccine associated inflammatory bowel disease or autism in a 14 year prospective study', *Lancet* **351**, 1327–8.

Rogers, E. M. (2003), *Diffusion of Innovations*, 5 edn, Free Press, New York.

Rosenzweig, M. R. & Schultz, T. P. (1982), The behavior of mothers as inputs to child health: the determinants of birth weight, gestation, and rate of fetal growth, *in* V. R. Fuchs, ed., 'Economic Aspects of Health', University of Chicago Press.

Ryan, B. & Gross, N. C. (1943), 'The diffusion of hybrid seed corn in two Iowa communities', *Rural Sociology* **8**, 15.

Samad, L., Tate, A. R., Dezateux, C., Peckham, C., Butler, N. & Bedford, H. (2006), 'Differences in risk factors for partial and no immunisation in the first year of life: prospective cohort study', *British Medical Journal* **332**, 1312–1313.

Schroeder, T., Pennings, J., Tonsor, G. & Mintert, J. (2007), 'Consumer food safety risk perceptions and attitudes: impacts on beef consumption across countries', *B.E. Journal of Economic Analysis and Policy* **7**.

Smeeth, L., Cook, C., Fombonne, E., Heavey, L., Rodrigues, L. C., Smith, P. G. & Hall, A. J. (2004), 'MMR vaccination and pervasive developmental disorders: a case-control study', *Lancet* **364**, 963–969.

Smith, A., Yarwood, J. & Salisbury, D. M. (2007), 'Tracking mothers' attitudes to MMR immunisation 1996 - 2006', *Vaccine* **25**, 3996–4002.

Suarez, L., Simpson, D. & Smith, D. (1997), 'Errors and correlates in parental recall of child immunizations: effects on vaccination coverage estimates', *Pediatrics* **99**, E3.

Taylor, B., Miller, E., Farrington, C. P., Petropoulos, M. C., Favot-Mayaud, I., Li, J. & Waight, P. A. (1999), 'Autism and measles, mumps, and rubella vaccine: no epidemiological evidence for a causal association', *Lancet* **353**, 2026–2029.

Taylor, B., Miller, E., Lingam, R., Andrews, N., Simmons, A. & Stowe, J. (2002), 'Measles, mumps, and rubella vaccination and bowel problems or developmental regression in children with autism: population study', *British Medical Journal* **324**, 393–396.

Uhlmann, V., Martin, C. M., Sheils, O., Pilkington, L., Silva, I., Killalea, A., Murch, S. B., Walker-Smith, J., Thomson, M., Wakefield, A. J. & O'Leary, J. J. (2002), 'Potential viral pathogenic mechanism for new variant inflammatory bowel disease', *Molecular Pathology* **55**, 84–90.

U.S. House of Representatives Committee on Government Reform (2000), 'Autism: present challenges, future needs–why the increased rates?', Hearing before the Committee on Government Reform. House of Representatives, One Hundred Sixth Congress, Second Session (April 6, 2000). Government Printing Office, Washington.

Victora, C., Vaughan, J., Barros, F., A, A. S. & Tomasii, E. (2000), 'Explaining trends in inequities: evidence from Brazilian child health studies', *Lancet* **356**, 1093–8.

Viscusi, K. (1997), 'Alarmist decisions with divergent risk information', *Economic Journal* **107**, 1657–1670.

Wakefield, A. J. & Montgomery, S. M. (2001), 'Measles, mumps, rubella vaccine: through a glass, darkly', *Adverse Drug Reactions and Toxicological Reviews* **19**, 265–283.

Wakefield, A. J., Murch, S. H., Anthony, A., Linnell, J., Casson, D. M., Malik, M., Berelowitz, M., Dhillon, A. P., Thomson, M. A., Harvey, P., Valentine, A., Davies, S. E. & Walker-Smith, J. A. (1998), 'Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children', *Lancet* **351**, 637–641.

Wooldridge, J. M. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge, Massachusetts.

Wright, J. A. & Polack, C. (2005), 'Understanding variation in measles-mumps-rubella immunization coverage: a population-based study', *European Journal of Public Health* **16**, 137–142.

Yarwood, J., Noakes, K., Kennedy, D., Campbell, H. & Salisbury, D. (2005), 'Tracking mothers attitudes to childhood immunisation 1991-2001', *Vaccine* **23**, 5670–5687.

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)

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	-0.154
	(0.252)**	(0.644)**	(1.101)	(1.046)
Year = 1999	-3.148	-1.700	-0.568	-0.725
	(0.334)**	(0.747)*	(1.082)	(1.106)
Year = 2000	-3.245	-1.660	0.083	-0.181
	(0.430)**	(0.920)†	(1.176)	(1.173)
Year = 2001	-6.656	-3.252	-1.990	-2.477
	(0.443)**	(0.922)**	(1.206)†	(1.222)*
Year = 2002	-8.912	-5.717	-3.353	-3.518
	(0.490)**	(0.893)**	(1.184)**	(1.272)**
Year = 2003	-10.790	-6.756	-2.862	-2.978
	(0.550)**	(1.123)**	(1.383)*	(1.505)*
Year = 2004	-9.838	-7.788	-6.939	-6.506
	(0.579)**	(1.216)**	(1.363)**	(1.554)**
Year = 2005	-6.912	-5.330	-4.571	-3.951
	(0.502)**	(1.156)**	(1.140)**	(1.300)**
Education (Age LFE $\geq$ 19)		8.848	7.214	6.338
		(2.903)**	(3.190)*	(2.847)*
Education $\times$ 1998		-3.195	-1.085	-0.311
		(2.433)	(2.897)	(2.643)
Education $\times$ 1999		-6.440	-4.893	-3.747
		(2.560)*	(3.139)	(2.964)
Education $\times$ 2000		-7.221	-4.729	-3.294
		(3.217)*	(3.318)	(3.080)
Education $\times$ 2001		-13.538	-11.624	-9.915
		(3.346)**	(3.713)**	(3.612)**
Education $\times$ 2002		-12.588	-9.304	-7.609
		(3.227)**	(3.614)*	(3.397)*

Continued on next page...

... table 2 continued

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Education × 2003		-14.867	-8.626	-7.271
		(3.788)**	(4.239)*	(3.953)†
Education × 2004		-8.847	-7.349	-6.761
		(4.084)*	(4.677)	(4.250)
Education × 2005		-7.548	-6.406	-6.801
		(3.711)*	(4.292)	(3.916)†
Household Income (£1,000)			0.036	0.058
			(0.033)	(0.034)†
H-Hold Income × 1998			-0.075	-0.089
			(0.048)	(0.049)†
H-Hold Income × 1999			-0.055	-0.069
			(0.046)	(0.047)
H-Hold Income × 2000			-0.083	-0.103
			(0.035)*	(0.037)**
H-Hold Income × 2001			-0.061	-0.078
			(0.042)	(0.043)†
H-Hold Income × 2002			-0.108	-0.142
			(0.043)*	(0.044)**
H-Hold Income × 2003			-0.192	-0.219
			(0.049)**	(0.049)**
H-Hold Income × 2004			-0.043	-0.074
			(0.048)	(0.047)
H-Hold Income × 2005			-0.036	-0.058
			(0.041)	(0.040)
Ethnicity: Black				-4.536
				(2.469)†
Ethnicity: Asian				-0.225
				(1.165)
Smoker (Current or Ex)				-1.126
				(0.637)†

Continued on next page...

... table 2 continued

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Nr Kids in H-Hold				0.329
				(0.234)
Lone Parent (Females)				-0.377
				(0.739)
GPs/1,000 Babies				0.047
				(0.027)†
GPs: Males				-0.017
				(0.070)
GPs: Age 35-64				0.129
				(0.074)†
GPs: Age 65 or above				-0.308
				(0.196)
Average Age of Adults				-0.038
				(0.032)
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	-0.229
	(0.259)**	(0.623)**	(1.042)	(0.985)
Subperiod 2 (1998-2000)	-0.542	0.076	0.039	-0.187
	(0.180)**	(0.348)	(0.632)	(0.666)
Subperiod 3 (2000-2003)	-2.572	-1.960	-1.374	-1.315
	(0.129)**	(0.313)**	(0.495)**	(0.463)**
Subperiod 4 (2003-2005)	2.070	0.763	-0.750	-0.382
	(0.147)**	(0.417)†	(0.558)	(0.506)
Education (Age LFE $\geq$ 19)		12.432	8.708	7.097
		(4.877)*	(5.417)	(4.987)
Education $\times$ Subperiod 1		-3.387	-1.373	-0.572
		(2.312)	(2.786)	(2.602)
Education $\times$ Subperiod 2		-2.714	-2.789	-2.443
		(1.098)*	(1.176)*	(1.175)*
Education $\times$ Subperiod 3		-1.833	-0.897	-0.844
		(1.098)†	(1.119)	(1.094)
Education $\times$ Subperiod 4		3.918	1.853	0.758
		(1.337)**	(1.447)	(1.439)
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	0.808	0.824	0.720	0.843	1.321	-1.373
	(0.687)	(0.680)	(0.673)	(0.681)	(0.690)†	(0.444)**
Year = 1999	0.326	0.311	0.466	0.377	0.917	-2.285
	(0.856)	(0.846)	(0.863)	(0.848)	(0.859)	(0.505)**
Year = 2000	1.088	1.082	0.985	1.098	1.914	-1.918
	(1.150)	(1.138)	(1.130)	(1.135)	(1.106)†	(0.407)**
Year = 2001	0.744	0.763	0.582	0.825	1.753	-0.395
	(0.974)	(0.967)	(1.006)	(0.975)	(0.989)†	(0.511)
Year = 2002	0.748	0.953	0.733	0.995	2.049	-1.262
	(1.420)	(1.402)	(1.396)	(1.415)	(1.385)	(0.520)*
Year = 2003	0.777	0.776	0.598	0.748	2.187	-3.283
	(1.003)	(0.992)	(1.045)	(0.993)	(1.009)*	(0.807)**
Year = 2004	0.034	-0.022	0.019	-0.017	1.501	-1.482
	(1.118)	(1.106)	(1.127)	(1.110)	(1.104)	(0.754)*
Year = 2005	-0.375	-0.370	-0.465	-0.372	1.341	-0.964
	(1.274)	(1.244)	(1.345)	(1.239)	(1.265)	(0.886)
Education (Age LFE $\geq$ 19)	4.083	3.941	4.044	4.006	4.441	-2.821
	(1.753)*	(1.758)*	(1.734)*	(1.758)*	(1.751)*	(1.018)**
Education $\times$ 1998	1.249	1.474	1.155	1.432	1.355	1.813
	(2.482)	(2.511)	(2.482)	(2.492)	(2.403)	(1.550)
Education $\times$ 1999	-1.621	-1.661	-1.761	-1.675	-2.035	3.876
	(1.965)	(1.963)	(1.991)	(1.959)	(1.917)	(1.412)**
Education $\times$ 2000	-3.299	-3.241	-3.789	-3.322	-3.932	2.875
	(2.172)	(2.165)	(2.225)†	(2.153)	(2.098)†	(1.160)*
Education $\times$ 2001	-4.219	-3.927	-4.493	-3.892	-4.018	3.162
	(2.238)†	(2.230)†	(2.338)†	(2.231)†	(2.254)†	(1.233)*
Education $\times$ 2002	-5.243	-4.800	-4.963	-4.873	-5.235	3.127
	(2.257)*	(2.260)*	(2.378)*	(2.269)*	(2.257)*	(1.398)*

Continued on next page...

... table 4 continued

Variable	**Polio**	**Diph.**	**Hib.**	**Tetanus**	**Pert.**	**Smears**
Education × 2003	-6.401	-6.345	-6.017	-6.495	-6.978	4.001
	(2.523)*	(2.461)**	(2.710)*	(2.479)**	(2.464)**	(1.300)**
Education × 2004	-5.851	-5.996	-5.702	-5.947	-6.496	1.922
	(2.416)*	(2.455)*	(2.368)*	(2.470)*	(2.466)**	(1.346)
Education × 2005	-6.377	-6.353	-6.449	-6.423	-6.996	3.534
	(2.454)**	(2.387)**	(2.460)**	(2.387)**	(2.384)**	(1.390)*
Household Income (£1,000)	0.011	0.012	0.005	0.013	0.022	0.007
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.016)
H-Hold Income × 1998	-0.054	-0.057	-0.048	-0.057	-0.064	0.020
	(0.032)†	(0.032)†	(0.032)	(0.032)†	(0.033)*	(0.020)
H-Hold Income × 1999	-0.031	-0.032	-0.034	-0.034	-0.036	0.006
	(0.029)	(0.028)	(0.030)	(0.028)	(0.030)	(0.023)
H-Hold Income × 2000	-0.060	-0.062	-0.049	-0.062	-0.067	-0.014
	(0.033)†	(0.032)†	(0.033)	(0.032)†	(0.032)*	(0.018)
H-Hold Income × 2001	-0.064	-0.067	-0.052	-0.071	-0.079	-0.011
	(0.028)*	(0.028)*	(0.029)†	(0.029)*	(0.031)**	(0.020)
H-Hold Income × 2002	-0.067	-0.073	-0.058	-0.075	-0.078	-0.021
	(0.051)	(0.051)	(0.050)	(0.051)	(0.051)	(0.019)
H-Hold Income × 2003	-0.044	-0.044	-0.033	-0.043	-0.054	0.013
	(0.031)	(0.030)	(0.034)	(0.030)	(0.031)†	(0.028)
H-Hold Income × 2004	-0.025	-0.021	-0.013	-0.023	-0.033	-0.000
	(0.034)	(0.033)	(0.033)	(0.033)	(0.034)	(0.022)
H-Hold Income × 2005	0.004	0.005	0.020	0.005	-0.008	-0.022
	(0.032)	(0.030)	(0.033)	(0.030)	(0.032)	(0.026)
Other Area Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Area-Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	852	852	852	852	852	852

Significance levels: $**$: 1% $*$: 5% † : 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)**
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)**

Continued on next page...

... table 6 continued

Variable	**MMR**	**Polio**	**Diph.**	**Tet.**	**Pert.**	**Hib**	**Hib+**
Nr. Siblings ≥ 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 (0.009)**		-0.028 (0.010)**	-0.022 (0.010)*	-0.022 (0.009)*	-0.022 (0.009)*
Eq. H-hold Income (£10,000)		-0.028 (0.008)**	-0.022 (0.009)**	-0.022 (0.009)**	-0.023 (0.008)**	-0.020 (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 (0.006)	-0.054 (0.046)	-0.100 (0.056)†
Eq. H-hold Income (£10,000)	0.022 (0.005)**	0.136 (0.042)**	0.079 (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%.

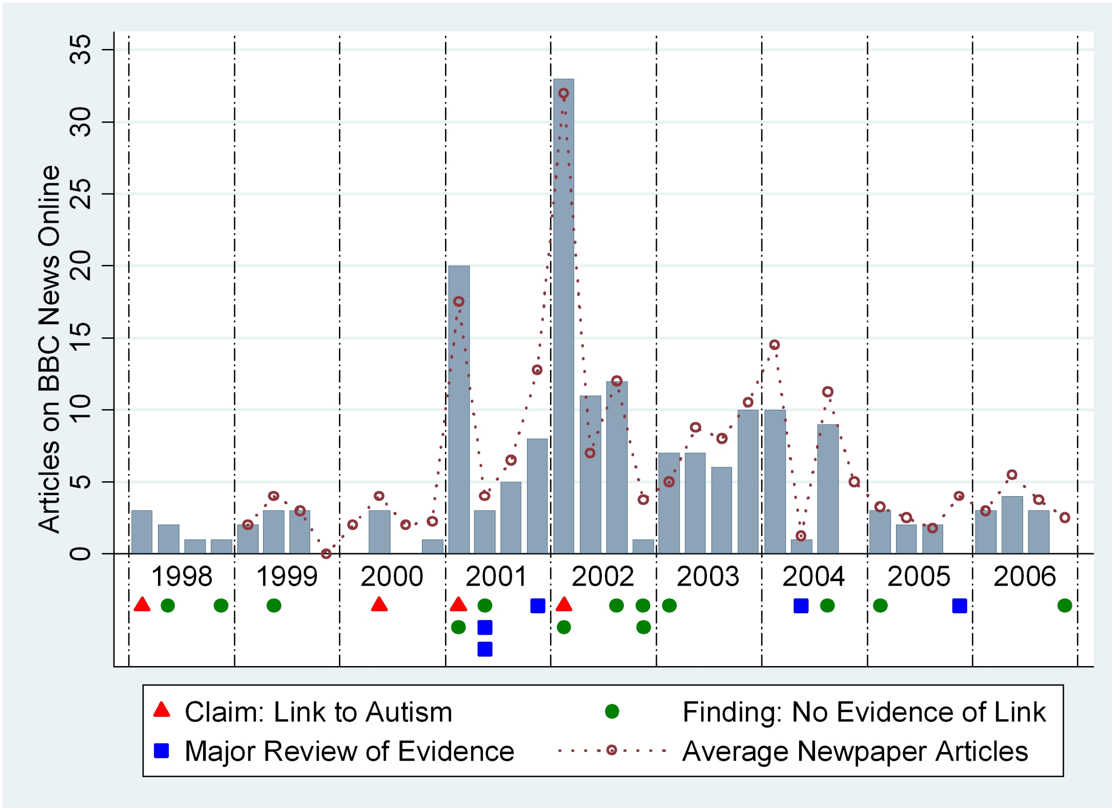

Figure 1: A timeline indicating the number of articles relating to the controversy appearing in BBC news online and in four main newspapers, as well as the timing of the publications of the main relevant pieces of research.

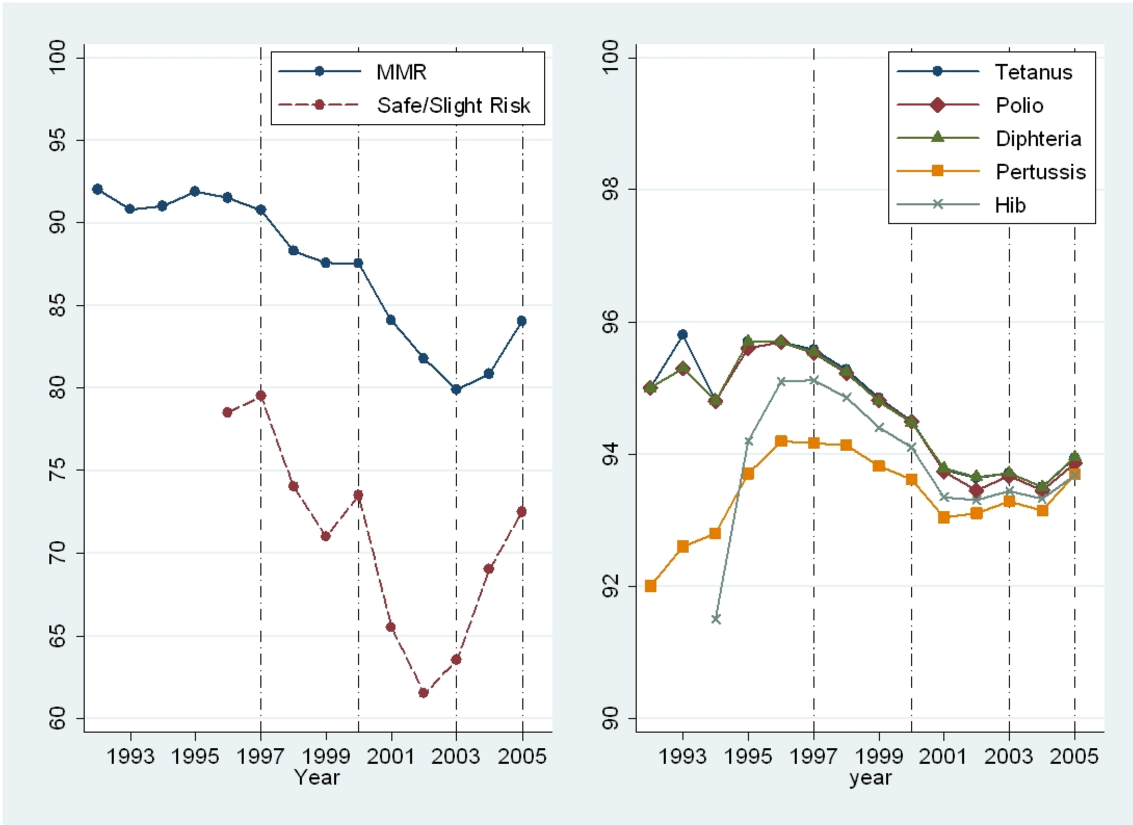

Figure 2: Trends in the uptake of immunizations; data for children who reach their second birthday and the proportion of mothers with young children who perceive the MMR vaccine to be either “completely safe” or pose a “slight risk”. (Source: Smith et al., 2007).

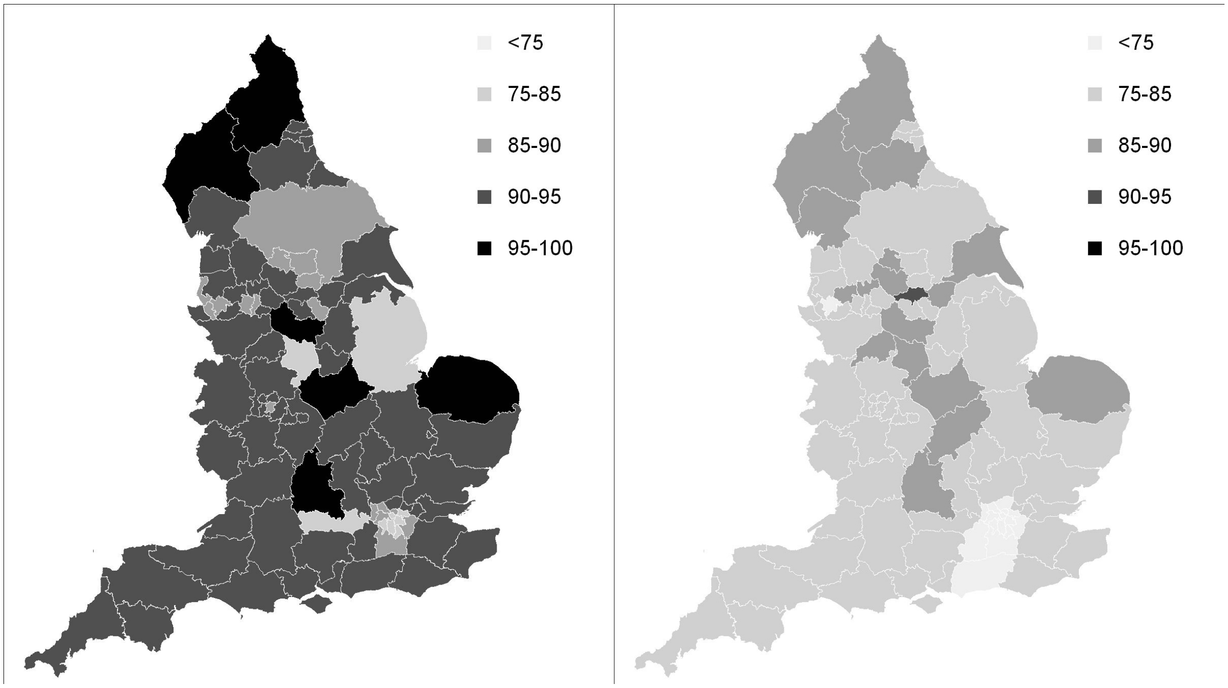

Figure 3: The MMR uptake rate in 1997 and 2003 across Health Authorities for children who reached their second birthdays.

CENTRE FOR ECONOMIC PERFORMANCE
Recent Discussion Papers

928	Christos Genakos Mario Pagliero	Risk Taking and Performance in Multistage Tournaments: Evidence from Weightlifting Competitions
927	Nick Bloom Luis Garicano Raffaella Sadun John Van Reenen	The Distinct Effects of Information Technology and Communication Technology on Firm Organization
926	Reyn van Ewijk	Long-term health effects on the next generation of Ramadan fasting during pregnancy
925	Stephen J. Redding	The Empirics of New Economic Geography
924	Rafael Gomez Alex Bryson Tobias Kretschmer Paul Willman	Employee Voice and Private Sector Workplace Outcomes in Britain, 1980-2004
923	Bianca De Paoli	Monetary Policy Under Alterative Asset Market Structures: the Case of a Small Open Economy
922	L. Rachel Ngai Silvana Tenreyro	Hot and Cold Seasons in the Housing Market
921	Kosuke Aoki Gianluca Benigno Nobuhiro Kiyotaki	Capital Flows and Asset Prices
920	Alex Bryson John Forth Patrice Laroche	Unions and Workplace Performance in Britain and France
919	David Marsden Simone Moriconi	'The Value of Rude Health': Employees' Well Being, Absence and Workplace Performance
918	Richard Layard Guy Mayraz Stephen Nickell	Does Relative Income Matter? Are the Critics Right?
917	Ralf Martin Laure B. de Preux Ulrich J. Wagner	The Impacts of the Climate Change Levy on Business: Evidence from Microdata
916	Paul-Antoine Chevalier Rémy Lecat Nicholas Oulton	Convergence of Firm-Level Productivity, Globalisation, Information Technology and Competition: Evidence from France

915	Ghazala Azmat Nagore Iriberri	The Importance of Relative Performance Feedback Information: Evidence from a Natural Experiment using High School Students
914	L Rachel Ngai Robert M. Samaniego	Accounting for Research and Productivity Growth Across Industries
913	Francesco Caselli Tom Cunningham	Leader Behavior and the Natural Resource Curse
912	Marco Manacorda Edward Miguel Andrea Vigorito	Government Transfers and Political Support
911	Philippe Aghion John Van Reenen Luigi Zingales	Innovation and Institutional Ownership
910	Fabian Waldinger	Peer Effects in Science – Evidence from the Dismissal of Scientists in Nazi Germany
909	Tomer Blumkin Yossi Hadar Eran Yashiv	The Macroeconomic Role of Unemployment Compensation
908	Natalie Chen Dennis Novy	International Trade Integration: A Disaggregated Approach
907	Dongshu Ou	To Leave or Not to Leave? A Regression Discontinuity Analysis of the Impact of Failing the High School Exit Exam
906	Andrew B. Bernard J. Bradford Jensen Stephen J. Redding Peter K. Schott	The Margins of US Trade
905	Gianluca Benigno Bianca De Paoli	On the International Dimension of Fiscal Policy
904	Stephen J. Redding	Economic Geography: A Review of the Theoretical and Empirical Literature
903	Andreas Georgiadis Alan Manning	Change and Continuity Among Minority Communities in Britain
902	Maria Bas	Trade, Technology Adoption and Wage Inequalities: Theory and Evidence

The Centre for Economic Performance Publications Unit
Tel 020 7955 7284 Fax 020 7955 7595 Email info@cep.lse.ac.uk
Web site http://cep.lse.ac.uk