Media Misinformation and Childhood Vaccination

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Abstract

In 1998, The Lancet published an article that erroneously linked the Measles, Mumps, and Rubella (MMR) vaccine to autism. A media scare questioning the safety of the MMR vaccine followed. To analyse the effects of exposure to different reporting during this scare, we exploit exogenous variation in newspaper readership caused by the boycott of The Sun (England's most widely read newspaper) in Liverpool. Using difference-in-differences and synthetic methods, we find that MMR vaccination rates fell 20% less in Liverpool compared to similar health authorities after the media scare. To analyse the reporting of newspapers around the time of the scare, we train word-embedding models on a corpus of newspaper articles. When compared to the most widely read newspaper in Liverpool after the boycott, The Sun's reporting was more likely to drive fears about the vaccine, even when fraud surrounding the original Lancet paper became a major news story. In line with the natural language processing analysis, the differences in vaccination rates are largest for cohorts of children due to be vaccinated just after major events in the MMR scandal.

1 Introduction

'*Fake news*', unfounded allegations of fraud in recent election cycles (Allcott and Gentzkow, 2017, Pennycook and Rand, 2021), and contradicting advice throughout the Covid-19 pandemic (Rocha et al., 2021, Bursztyn et al., 2020), highlights a modern challenge of misinformation. However, misinformation is not an entirely modern phenomenon. Even in coverage of facts, such as the safety and efficacy of vaccines, media outlets can diverge in terms of what they chose to report, as well as how to cover the same stories. Despite this, there remains a gap in our understanding of how individuals update their beliefs and modify their behaviors in response to differential reporting (including outright misinformation) by media outlets about the same topics.

A notable historical instance of media misinformation with significant implications was the MMR vaccine scare during the early 2000s. A paper published in The Lancet erroneously linked vaccines to autism via a bowel disease (Wakefield et al., 1998). Certain media outlets in England highlighted the alleged connection between the MMR vaccine and autism, with coverage peaking in early 2002 amid speculation about the vaccination status of the Prime Minister's son. From 2004 onwards, coverage shifted towards the fraudulent nature of the research underpinning these claims, with the original Lancet paper being retracted in 2010. However, even in light of the fraud, some media outlets still questioned the safety of the vaccine, validating parents' fears. The media scare resulted in a significant decline in vaccination rates (Motta & Stecula, 2021), likely being a major factor in outbreaks in mumps and measles across England (Calvert et al., 2013, Thompson et al., 2023).

Despite, the original Lancet paper being widely criticized in the scientific community upon publication (Taylor et al., 1999), its claims continue to be an important reference for modern vaccine skeptics. Andrew Wakefield - the paper's primary author - has become a figure head for the movement. Originally, the safety concern was exclusively with the combined MMR vaccine, with Andrew Wakefield suggesting that separate vaccines[1] for measles, mumps, and rubella would be safer. Over time the

[1]for which Wakefield had filed a patent for in 1997 (Deer, 2011)

story evolved into the idea that vaccines generally cause autism (Gabis et al., 2022). This misinformation became increasingly salient during the Covid-19 pandemic (Adhikari and Cheah, 2021, Bursztyn et al., 2020).

Even though media coverage during the vaccine scare differed between newspapers, analysing the causal effect of these differences in reporting is empirically challenging. Media preferences are influenced by various factors, including age, class, and political beliefs, which can influence vaccination decisions independently of media exposure. To address this endogeneity issue we use the boycott of The Sun in Liverpool as a source of plausibly exogenous variation in newspaper readership[2]. This boycott was a response to The Sun's misinformation after the Hillsborough sporting disaster in which 97 Liverpool FC fans died. We provide evidence that this boycott is strong in magnitude, long-lasing, and geographically restricted to Merseyside. Survey data from the time suggest that people in Liverpool substituted readership of The Sun for competing tabloid newspaper The Daily Mirror.

We argue that the change in newspaper readership caused by the boycott reduced exposure to misinformation during the MMR vaccine scare for people in Liverpool. A keyword search for relevant articles shows that The Sun published articles highlighting the alleged link between MMR and autism at the start of the scare. The Sun published fewer articles when the fraud surrounding the Lancet paper was uncovered, and continued to question the vaccine's safety. In contrast, during the height of the scare, The Daily Mirror published articles reassuring readers of the safety of the MMR vaccine and published more articles covering Andrew Wakefield's fraud. To empirically compare the reporting of the two newspapers, we train word embedding models on the text from a large number of newspaper articles. In Daily Mirror articles, 'MMR' was more closely associated with words such as 'Scare', and 'Conspiracy', while The Sun had a closer association for words like 'Risk' and 'Autism'. 'Wakefield' was associated with 'Dishonest' in The Daily Mirror, while The Sun was far more likely to call him 'Respected'.

[2]inspired by (Foos & Bischof, 2020)

Using a difference-in-differences design, we estimate that vaccination rates for MMR in Liverpool declined 15 - 25% less than in other Health Authorities in England. Event studies and synthetic methods show that the treatment effects are largest for children who were due to be vaccinated just after major events in the MMR scare. We see that parents not only vaccinate their children less when exposed to more misinformation, but that correction of said misinformation (because of the fraud in the original Lancet paper), increases vaccination rates. This paper contributes to a growing body of literature on the effects of misinformation, particularly in high-stakes contexts such as vaccine uptake (Bursztyn et al., 2020, Bartoš et al., 2022). We also contribute to understanding of the role media plays in shaping public health outcomes. The remainder of this paper is structured as follows: Section 2 provides context regarding the Hillsborough Disaster and how this effected newspaper readership, the MMR vaccine in England, and the MMR vaccine scare. We provide evidence for differences in reporting between papers on the MMR scare. Section 3 covers the data used. Section 4 outlines the empirical strategy. In Section 5, we present the main findings, while Section 6 discusses the robustness of these results.

2 Context

2.1 The Hillsborough Disaster & The Sun Boycott

During a football game in Sheffield between Liverpool and Nottingham Forrest on the 15^{th} of April 1989, a human crush in the standing pens allocated to Liverpool supporters resulted in the deaths of 97 people (94 on the day). Around ten minutes before the game was due to start - despite the pens already being at capacity - police opened a large exit gate to allow more supporters to enter. It has been estimated that the amount of supporters in the central pens was almost double the safe capacity. Despite the overcrowding, the game continued as scheduled. It was called off after six minutes of play after a policeman ran onto the pitch to alert the referee as supporters were climbing perimeter gates to avoid the crush (BBC, 2009).

After the disaster an inquiry into the causes of the Hillsborough disaster was overseen by Lord Justice Taylor. It found that the main reason for the disaster was the failure of police control. In 2009 the British government instituted the Hillsborough Independent Panel to investigate the disaster, this concluded that no Liverpool fans were responsible in any way for the disaster, and that its main cause was a "lack of police control". Contrary to the findings of these enquiries the South Yorkshire Police fed the press false stories suggesting that hooliganism and drunkenness by Liverpool supporters had caused the disaster.

(a) "The Truth" (1989)

(b) "The Real Truth" (2012)

Figure 1: Reporting on Hillsborough Disaster by The Sun

Four days after the disaster, the British tabloid newspaper The Sun ran the front page headline "THE TRUTH" (shown in Figure 1(a)) which shifted blame from the police, onto the Liverpool fans themselves. Originally, The Sun remained unapologetic about its 1989 article, leading to a boycott of the newspaper by Liverpool football supporters. The stubbornness of The Sun lead to a coordinated boycott around the Merseyside[3] area, with even supporters of local rival team Everton showing solidarity in the boycott. Figure 1(b) shows a more recent front page headline in 2012 from

[3]the Metropolitan county which contains the city of Liverpool

The Sun in which they apologise for the original article. Despite this apology and admission of guilt, the boycott is still on going to this day.

While newspapers do not report regional sales figures to measure the extent of the boycott, survey data can be used as a proxy. The British Social Attitudes survey (BSA) (Park et al., 2014) asks respondents which newspaper they regularly read. Figure 2b plots the newspaper mix in the county of Merseyside. After the Hillsborough disaster, self-reported readership of The Sun fell from 25% to 12% in Merseyside[4]. The most common substitute for The Sun in Merseyside seems to be The Mirror. Contextually, this switch seems plausible - The Sun and Mirror are both tabloid newspapers read primarily for their entertainment and sports.

There is also evidence that the boycott of The Sun is still salient today. For example, in 2017 Liverpool football club banned journalists from The Sun from their stadium and training ground, over the newspaper's coverage of Hillsborough (Conn, 2017). Foos and Bischof, 2020 provide further evidence for the boycott of The Sun in Liverpool via telephone surveys. They find that 62% of newspaper agents in the Merseyside area did not sell The Sun, and this rises to 86% in the city of Liverpool, with many of the newspaper agents interviewed in Liverpool bringing up the boycott unprovoked. By contrast, in the adjacent counties Lancashire and Cheshire, only 10% and 12% of agents report not selling The Sun respectively. This 'supply-side' survey evidence combined with the 'demand-side' survey data shown in Figures 2 and A.6 provide strong evidence that the boycott of The Sun took place, is strong in magnitude, and is geographically restricted to the Merseyside area.

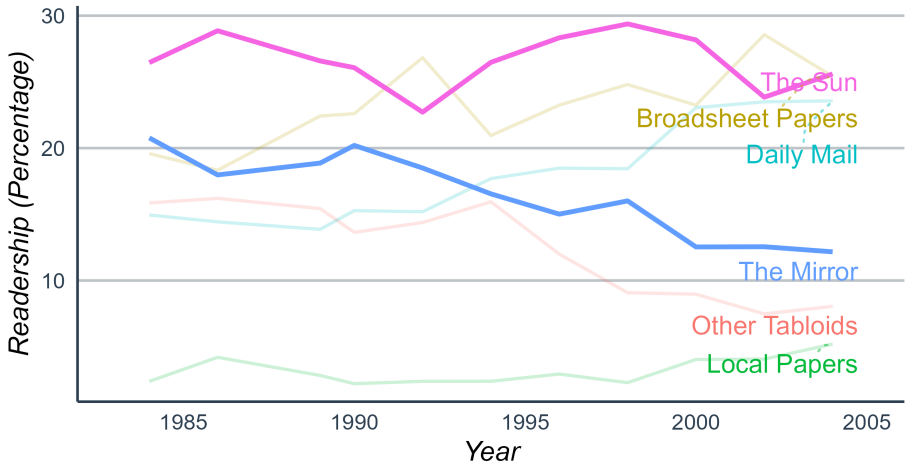
2.2 MMR Vaccine Scare

An article published in The Lancet in 1998 (Wakefield et al., 1998) linked the combined MMR vaccine to autism. While originally dismissed by the scientific community

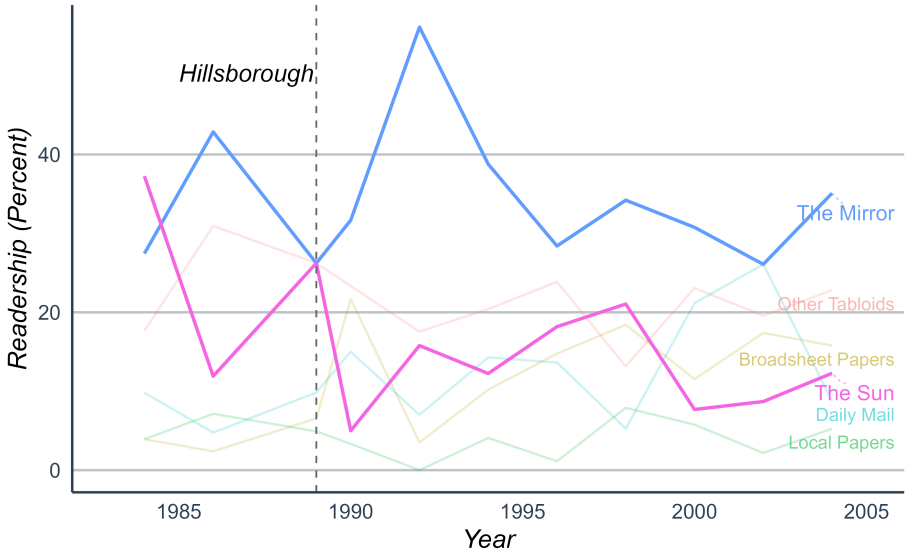
[4]Figure A.6 shows that this difference is statistically significant, and that there is no evidence of spillovers to nearby regions.

Figure 2: Newspaper Mix in England and Merseyside

(a) **England**



(b) **Merseyside**



Note: This figure plots the readership percentage of different newspapers from British Social Attitudes (BSA) respondents in England (a), and Merseyside (b). Conditional on reading a newspaper regularly, respondents choose which is the paper they read the most. Liverpool is the most populous city in the county of Merseyside. Broadsheets include: Telegraph, Financial Times, Guardian, Independent, and Times.

(Taylor et al., 1999), the paper's findings and author became the topic of a public health scare (Anderberg et al., 2011). Figure 3 shows a timeline of key events during scare. Media coverage of the scare increased from September 1999 peaking in early 2002 with a story about then prime minister Tony Blair's son. Because of the scare, the government reiterated the safety and efficacy of the MMR vaccine. This lead to news coverage questioning if the prime minister's son (who was around two years old - an age at which most children are expected to have had their first MMR dose) had been vaccinated, which Tony Blair didn't confirm until February 2002.

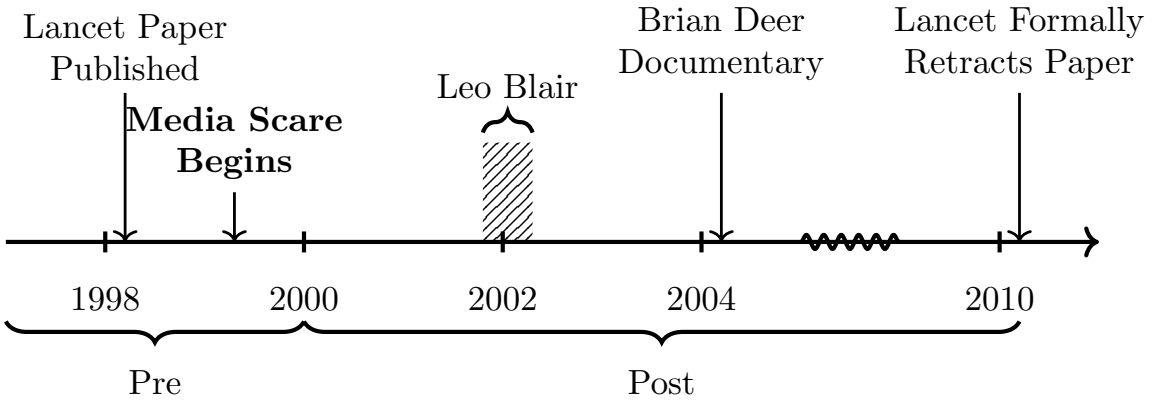


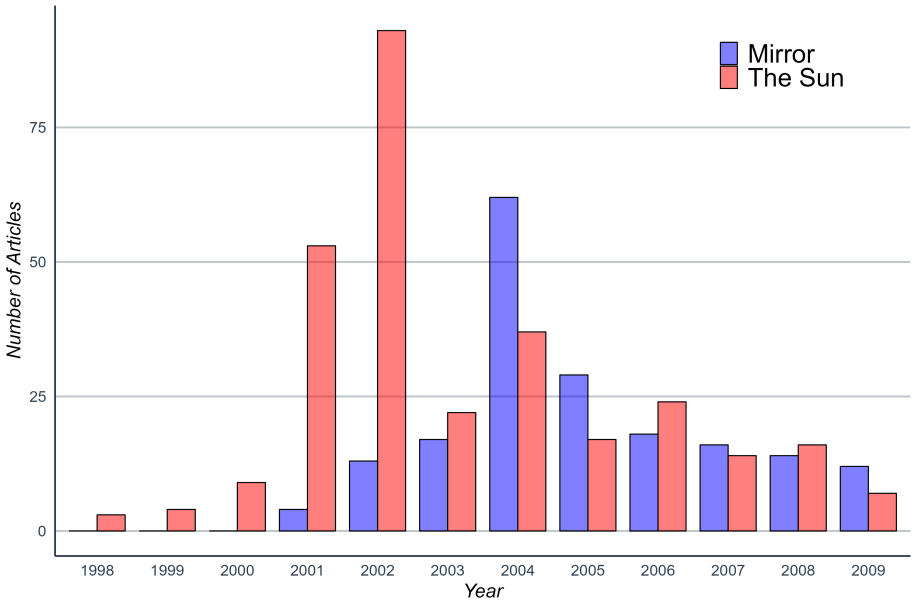
Figure 3: Key Events in MMR Vaccine Scare

Media interest piqued again in 2004 when an undeclared conflict of interest in the original Lancet paper came to light. Two years before the 1998 Lancet paper was published, the main author of the paper was hired by a lawyer to serve as an expert witness in a planned class action seeking compensation for "vaccine damage". Media attention further intensified when Brian Deer's documentary *MMR: What They Didn't Tell You* was broadcast in November 2004. Brian Deer's reporting weakened the credibility of the original Lancet paper. His findings, and the legal cases that followed resulted in The Lancet formally retracting the paper in February 2010, and Andrew Wakefield (the main author of the paper) being struck off the medial record four months later.

2.3 Newspaper Reporting of the Scare

Here we compare the reporting of the two main newspapers relevant to people in Merseyside: The Sun, the UK's most widely read paper, which was boycotted in Merseyside; and The Daily Mirror, the paper that was most often read in Merseyside, after the boycott, as shown in Figure 2. Figure 4, plots the number of articles

Figure 4: Count of Relevant Articles during the Scare



Note: This figure plots the total number of articles published by the Daily Mirror and The Sun that are in the Factiva topic of infant/child health and contain at least one of the following words: *"MMR, vaccine, jab, wakefield"*.

published in both papers that match a keyword search about the MMR vaccine. Neither paper published many articles directly after The Lancet paper was published in 1998, although The Sun's reporting increased by the year 2000 with a total of 10 articles (up to this point The Mirror had yet to publish a single relevant article). Reporting by The Sun peaked in the year 2002, when most articles were about the uncertainty surrounding the safety of the vaccine, and Tony Blair's son. In contrast, The Mirror published more articles in 2004, when articles were calling into doubt the credibility of the original Lancet paper.

Figure 5 showcases examples of articles from the two newspapers before and after 2004. The Sun was early to reporting the potential link between the vaccine and autism, while when it did report, The Mirror was more sceptical of the link. Even after Brian Deer's 2004 exposé, The Sun continued to cast doubt on the vaccine's safety, hinting at unresolved fears, despite emerging evidence that discredited the initial claims linking MMR to autism.

Figure 6 compares the reporting of the two newspapers from 2000 - 2010 using words embedding models. Word embedding models measure the semantic relationships between words by representing them in a high-dimensional space. The similarity between word vectors is quantified using cosine similarity, which ranges from -1 to 1. Values closer to 1 indicate a stronger semantic relationship, suggesting that the words share similar contexts or meanings, while values near -1 indicate dissimilarity (Mikolov, Chen, et al., 2013), (Mikolov, Sutskever, et al., 2013). To compare the reporting between the two newspapers we train word embedding models on the text from 4300 Daily Mirror articles and 3643 articles from The Sun using the word2vec package from the Gensim library in Python (Rehurek & Sojka, 2011).

Figure 5: Selected quotes from The Sun and Daily Mirror covering the MMR scare

The Sun, 14^{th} *Jun 2000*

Three children given the MMR vaccine at the same health centre within a four-month period have developed autism, it was revealed last night... "There is strong circumstantial evidence to point to the MMR jab as the reason."

The Sun, 6^{th} *Feb 2002*

He (Tony Blair) knows the MMR controversy is already out of control. Many mums are now refusing to allow their children to have the jab. They simply do not believe the Government when it says MMR is safe. To be frank, we agree with them.

Daily Mirror, 7^{th} *Feb 2002*

Who backs combined MMR jab? British Medical Association and Royal College of Nursing. And who doesn't? The Sun and Daily Mail. Consider the facts. In 90 countries MMR is used to inoculate children. The UK is the only one in which there is any suggestion it is not safe.

(a) Selected quotes from articles before 2004

The Sun, 26^{th} *Feb 2004*

THE current confusion over the MMR jab is a nightmare for parents. They all want to do the best for their kids. But to hear that the doc who issued the warning about autism had a hidden agenda does not bear thinking about. We may never be sure now whether the jab is safe.

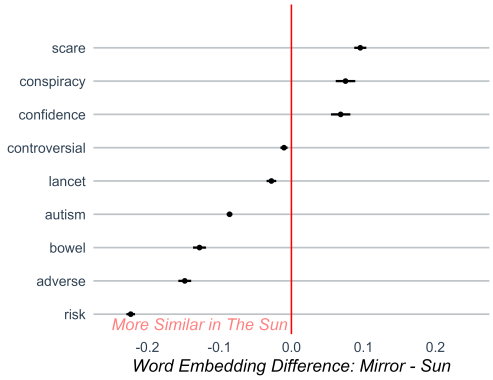
Daily Mirror, 4^{th} *Mar 2004:*

MOST of the scientists who found a link between the MMR vaccine and autism have changed their minds, it was revealed yesterday. Ten of the 13 authors ... have announced they are retracting their conclusion. Dr Andrew Wakefield, stands by the findings

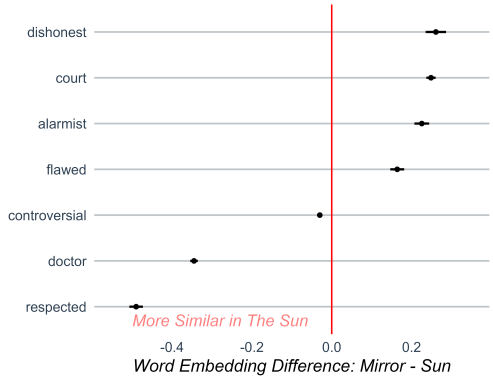
(b) Selected quotes from articles after 2004

Figure 6: Word Embedding Comparisons between The Sun and Daily Mirror

(a) Semantic Closeness to 'MMR'



(b) Semantic Closeness to 'Wakefield'



Note: In these figures we present the difference between cosine similarities from word embedding models trained using text from 4,300 articles from The Daily Mirror and 3,643 articles from The Sun from 2000 - 2010. Estimates are bootstrapped, we sample 60% of the articles from each dataset with replacement 400 times. Articles accessed via Factiva, with the following keyword search: *Vaccin* or Immunization* or jab or jabs or MMR or measles or mumps or rubella or autism or autistic or "Andrew Wakefield" or "Dr Wakefield" or "Brian Deer"*

Figure 6a shows that in the sample of Daily Mirror articles, 'MMR' was more closely associated with words such as 'Scare', and 'Conspiracy', while The Sun had a closer association for words like 'Risk', 'Autism', and 'Bowel'. This suggests that when reporting on the MMR vaccine, The Sun was more likely to highlight the reported link to autism via a bowel disease. For the word 'Wakefield' (as in Andrew Wakefield), the articles from The Daily Mirror associated him with 'Dishonest', while The Sun 'Respected'. It is worth noting that this type of analysis only allows for the comparison of cosine similarities for words that appear in both samples. For example the words "Wakefield" and "Misinformation" have a cosine similarity of 0.55 in the sample of Daily Mirror articles. However the word "Misinformation" does not appear once in the sample of articles from The Sun.

2.4 MMR Vaccination in England

The combined MMR vaccine provides protection against Mumps Measles and Rubella. In England, the first dose is administered to children after their first birthday, a process that involves parents taking their child to a GP surgery and providing consent for vaccination. Vaccination is optional, not being required for school attendance (Rough et al., 2022). Figure 7 plots the percentage of children in England who have had the first dose of MMR at the age of 24 months. After being introduced in 1988, uptake quickly reached 90% and remained high until the vaccine scare. From the year 2000 to 2004 MMR vaccination rates in England dropped 7% points, from 87% to 80% far below the 95% threshold required for herd immunity (Organization et al., 2019). In the years following this parts of England experienced measles outbreaks (Jansen et al., 2003), with the first death from the disease occurring the the UK for 15 years in 2006 (Asaria and MacMahon, 2006). Following these outbreaks, and the stories highlighting the flaws in the paper that started the scare, vaccination rates recovered to pre-scare levels by 2009.

3 Data

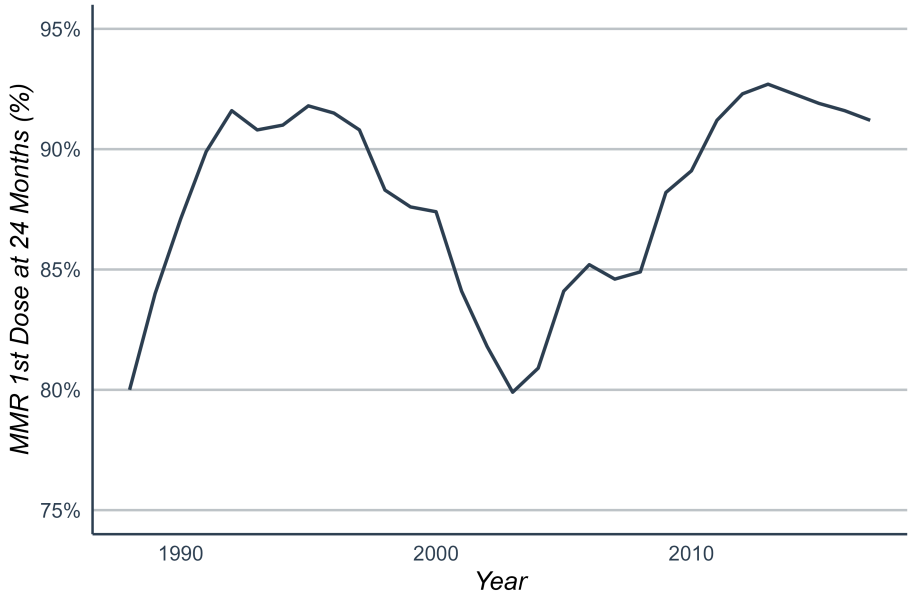
To measure the effect of the boycott of The Sun in Liverpool on MMR vaccination rates, we combine sources of information on vaccination rates, demographic characteristics, and health outcomes.

3.1 Childhood Vaccination Rates

For information on childhood vaccination rates in England we use data from the "Cover of vaccination evaluated rapidly" (COVER) program (Begg et al., 1989). The COVER program provides annual information on the proportion of children in England who have received their first dose of MMR[5] at 24 months old. Each annual

[5]as well as other vaccines including Haemophilus Influenzae Type b (Hib), Polio, Pertussis, Diphtheria, and Tetanus.

Figure 7: MMR Vaccination Rate in England



Note: This figure plots the percentage of children aged 24 months who had received their first dose of MMR in England. Data from the Cover of Vaccination Evaluated Rapidly program.

vaccination rate reflects the vaccination percentage for a cohort of children that become 24 months of age from the 1st of April to the 31st of March. For example, the vaccination rate in the year 2000, reflects the vaccination rate for children born between the dates April 1st 1998 and March 31st 1999. Annual rates for the whole of England are reported from the introduction of MMR in 1988, as shown in Figure 7.

Vaccination rates for smaller regions in England are available from 1997 onwards. The exact unit of observation vary year on year, depending on the administrative bodies of the National Health Service (NHS) at the time. From 1997 until 2002 vaccination rates were reported at the Health Authority (HA) level, from 2003, they are reported at the Primary Care Organisation (PCO) and later the Primary Care Trust (PCT) level. For a stable unit of observation, we aggregate the data to the HA level[6] - the largest unit COVER data is reported at. This aggregation results in data with

[6]as in Anderberg et al., 2011

vaccination rates for each HA from 1997-2008.

3.2 Demographic Characteristics and Health Outcomes

Demographic and health differences between Health Authorities may impact the decision to vaccinate children, independently of media exposure. To control for such characteristics, we use data from the Health Survey for England (HSE) (Mindell et al., 2012), an annual survey in which respondents provide demographics and health information. From 1997-2002 the survey provides geographic information about its respondents at the HA level. This representative survey provides annual information about demographic characteristics and self-reported health outcomes. Examples of these can be seen in Table A.2, which compares Liverpool to all other HAs in England.

4 Empirical Strategy

To analyse the impact of the boycott of The Sun in Liverpool on vaccination rates we use three related approaches. First, we estimate difference-in-differences specifications, as shown in Equation 1. Treated units are those in the Health Authority of Liverpool, after the start of the media scare in 2000. A specification where treatment is defined by those in the county of Merseyside will also be estimated, that is including also the HAs of Sefton, St. Helens & Knowsley, and Wirral. Since the countries of Scotland, Wales, and Northern Ireland have different public health bodies, England (less Merseyside) is used as the control group. Equation 1 outlines the two-way fixed effect model used:

$$Y_{h,t} = \alpha_c + \gamma_t + \delta X_{h,t} + \beta Treat_{h,t} + \epsilon_{h,t} \tag{1}$$

Here $Y_{h,t}$ is the vaccination rate in health authority h, in year t. α_c are health authority fixed effects, that control for time invariant health authority characteristics. γ_t are time fixed effects, and $X_{h,t}$ are aggregate health authority controls, including age, education, ethnicity and income. $Treat$ is the binary treatment variable, equal to one if the health authority is in Liverpool after the start of the scare. β is the coefficient of interest, the average treatment effect on the treated. Standard errors $\epsilon_{h,t}$, are clustered at the health authority level.

Second, we explore event study designs by estimating regressions specified by Equation 2.

$$Y_{h,t} = \alpha_c + \gamma_t + \sum_{t \neq 1999} \beta_t \cdot Year_t \cdot Treat_{h,t} + \epsilon_{h,t} \tag{2}$$

Variables are defined in the same way as in Equation 1. Here $Year_t$ is a dummy for each year in the COVER sample. This specification allows for the analysis of treatment effects over time, as the MMR scare and scandal that followed it developed.

Third, we use the *synthetic control method* proposed by Abadie and Gardeazabal, 2003 to construct a *synthetic*-Liverpool Health Authority that best approximates the relevant characteristics of Liverpool during the pretreatment period. To construct the *synthetic*-Liverpool HA we use MMR vaccination rates as well as household income and education from the HSE. These were chosen as education has been shown to be important for predicting changes in childhood vaccination during this scare (Anderberg et al., 2011), and Table A.2 shows that the average household income in Liverpool is lower than average.

5 Results

Table 1 shows estimations of Equation 1, with different vaccines as outcome variables. Panel A is a model in which treatment is defined as Liverpool, while Panel B uses the whole county of Merseyside as the treated group. In both panels the estimated treatment effect on MMR vaccination rates is strongly statistically significant. Given

the drop in vaccination rates in England following the scare were around 7% points, the effect sizes of 1.5 - 2.2% points explain around 15% to 25% of the fall in vaccination rates. The estimated treatment effect is larger when treatment is defined as Liverpool HA, compared to all HAs in Merseyside, this aligns with the fact that the boycott of The Sun is strongest in the city of Liverpool (Foos & Bischof, 2020).

Table 1: Two-Way Fixed Effect Model, Different Vaccines

	(1)	(2)	(3)	(4)	(5)
	MMR	Diphtheria	Pertussis	Polio	Hib
Panel A: Treatment defined as **Liverpool**					
ATET	2.165***	1.008***	1.217***	1.033***	1.664***
	[0.360]	[0.229]	[0.208]	[0.230]	[0.229]
Panel B: Treatment defined as **Merseyside**					
ATET	1.508***	0.367	0.515	0.315	0.582
	[0.528]	[0.490]	[0.485]	[0.505]	[0.560]
Control Mean	85.10	94.39	93.75	94.36	94.11
N	1158	1159	986	1159	1159

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Treatment effects that are also estimated for other vaccines. In panel A these are also strongly statistically significant, although smaller in magnitude than MMR. For panel B the estimates are not significant, but are all positive. One reason for a detectable effect of the MMR media scare on other vaccines could be spillovers. While the original scare was specific to the combined MMR vaccine causing autism, over time this has evolved in anti-vaccine rhetoric to simply 'vaccines cause autism' (Gabis et al., 2022). An alternative explanation for this is that the simple two-way fixed effects model is not controlling for factors that vary by region and time and

affect health decisions. To account for this possibility, we include the vaccination rate for Polio as a control in the final column of Table 2.

Table 2: Effect of Initial Scare: Two-way Fixed Effect Model with Controls

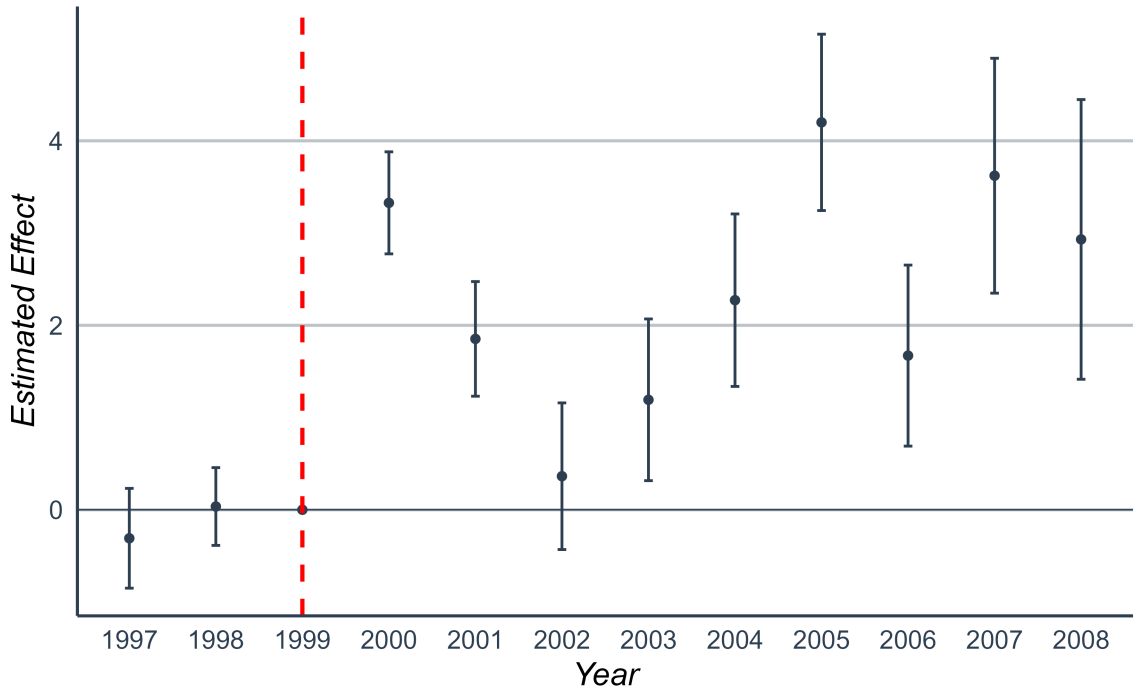
	(1)	(2)	(3)	(4)	(5)	(6)
	MMR	MMR	MMR	MMR	MMR	MMR
ATET	1.449***	1.597***	1.615***	1.403***	1.504**	1.061***
	[0.377]	[0.362]	[0.369]	[0.395]	[0.581]	[0.272]
Ethnicity	—	✓	✓	✓	✓	✓
Age	—	—	✓	✓	✓	✓
Income	—	—	—	✓	✓	✓
Education	—	—	—	—	✓	✓
Polio	—	—	—	—	—	✓
Control Mean	85.10	85.10	85.10	85.10	85.10	85.10
N	517	517	517	517	517	517

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2 reports estimates of Equation 1 with specifications differing by the controls included. Treatment is defined as Merseyside. Since the HSE is only reported at a local level until 2002, this analysis is limited to the sample 1997-2002. In effect, this means that this specification measures the impact of the initial vaccine scare, with reporting (or lack there of) about the link between MMR and autism. Estimated effects are stable in columns (1) through (5), suggesting that observable differences between Liverpool and other HAs are not driving the results. Column (6) includes polio vaccination rates as a control variable, here treatment is still estimated to increase vaccination rates by 1% point, even though there are spillovers from the MMR reporting (Anderberg et al., 2011).

Figure 8 is an event study plot, showing how MMR vaccination rates of children

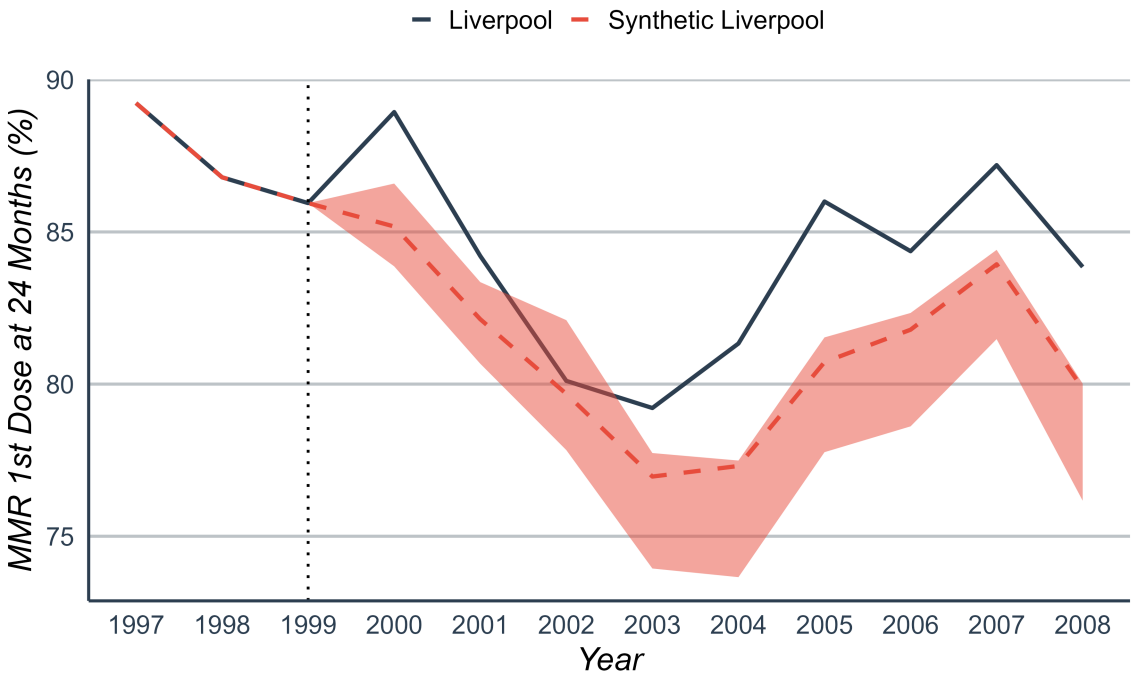
Figure 8: Event Study - Effect of Treatment (Liverpool) on MMR Vaccination at 24 months old



Note: This figure plots an event study resulting from running regression 2. MMR vaccination rates at 24 months is the outcome variables, comparing vaccination rates in Liverpool to all other Health Authorities in England.

evolved over time in Liverpool compared to the rest of England (less Merseyside). There is no evidence for differences from 1997 - 1999. However vaccination rates in Liverpool were roughly 3% points higher at the end of the year 2000, after the media scare had started. These estimates remain positive for the rest of the sample, peaking again in 2005. This was after the Brain Deer documentary which was widely reported on in The Mirror, relative to The Sun. Figure A.8 shows that this result is robust to only including Health Authorities that contain a major city for counterfactual estimation.

Figure 9: Observed Liverpool MMR vaccination rates compared to synthetic Liverpool with 90% Prediction Intervals



Note: This Figure compares vaccination rates for MMR at 24 months old for Liverpool and its synthetic counterpart with 90% predicition intervals. The predictor variables are MMR vaccination rate, household income, and education. The health authorities in the donor pool with the highest weights are North Staffordshire, Manchester, Croydon, and Lancashire.

Figure 9 shows the trend in MMR vaccination rate in Liverpool, compared to a synthetic control. In the construction of *synthetic*-Liverpool, the health authorities with the highest weights are, North Staffordshire, Manchester, Croydon, and Lancashire. *Synthetic*-Liverpool very closely resembles pre-2000 MMR vaccination rates in Liverpool. After the media scare began, vaccination rates between the two diverge, with vaccination rates remaining higher in Liverpool compared to its synthetic counterpart. The gap between them widens the year after major developments in

the MMR scandal. In 2003, the year after the story about the uncertain vaccination status of Tony Blair's son, the difference becomes statistically significant again. The difference further increases after the reporting of Brain Deer in 2004.

6 Conclusion

The boycott of The Sun, higher vaccination rates in Merseyside, and the analysis of differences in newspaper reporting of the MMR vaccine scare paint a congruent picture. Individuals in Merseyside were less exposed to the misinformation surrounding the safety of the MMR vaccine perpetuated by the UK's most widely read newspaper. This change in readership was a result of a plausibly exogenous event - a boycott caused by The Sun's misinformation surrounding a sporting disaster a decade before the vaccine scare. Overall estimates for the effect on MMR vaccination rates of people in Merseyside being less exposed to misinformation surrounding the vaccine scare are 1 - 2% points, depending on the specification used. In the context of the MMR vaccine scare in England, this explains 15-25% of the decrease in vaccination rates.

There are several mechanisms through which the higher vaccination rates in Merseyside could have occurred. As highlighted in Figures 2 and 4, people in Merseyside were less likely to be exposed to newspaper articles covering the supposed link between the vaccine and autism. This may have meant that Merseyside residents were simply less aware of the link to autism, especially in the early years of the scare. Another potential mechanism relates to the nature of the boycott of The Sun in Merseyside. The boycott occurred because of The Sun's misinformation as to the cause of the Hillsborough disaster. This highly salient case of media misinformation may have made Merseyside residents more skeptical of media reporting in the future - meaning that even exposed to misinformation during the vaccine scare, Merseyside residents may have updated their beliefs and behaviours less than people from other parts of England. A related mechanism could be that people from Merseyside *actively disbelieve* reporting by The Sun more than in other parts of England because of Hillsborough.

Together with these potential mechanisms, the estimates shown in Figure 8, can tell us something about the dynamics of the vaccine scare. Treatment effects were high in the year 2000 and 2001, when the difference in number of articles by different newspapers may have impacted knowledge of the vaccine scare at the extensive margin. Estimates for treatment effects become statistically insignificant in the years 2002 and 2003, when the vaccine scare had been widely reported on - to the point where most parents were likely aware of the reported link to autism. However, treatment effects become significant from 2004 onward, when the credibility of the original Lancet paper and its author were questioned. The academic misconduct was more widely reported on in newspapers that people in Merseyside read, while The Sun still called into question the safety of the vaccine. This potentially shows that the media can be effective in actively combating misinformation.

This paper establishes causal evidence for the effect of misinformation presented by news media in a high-stakes public health setting. These results highlight the need for accurate information in public discourse and the role media plays in shaping public health outcomes.

References

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the basque country. *American economic review*, *93*(1), 113–132.

Adhikari, B., & Cheah, P. Y. (2021). Vaccine hesitancy in the covid-19 era. *The Lancet Infectious Diseases*, *21*(8), 1086.

Allcott, H., & Gentzkow, M. (2017). Social media and fake news in the 2016 election. *Journal of economic perspectives*, *31*(2), 211–236.

Anderberg, D., Chevalier, A., & Wadsworth, J. (2011). Anatomy of a health scare: Education, income and the mmr controversy in the uk. *Journal of Health Economics*, *30*(3), 515–530.

Asaria, P., & MacMahon, E. (2006). Measles in the united kingdom: Can we eradicate it by 2010? *BMJ*, *333*(7574), 890–895.

Bartoš, V., Bauer, M., Cahlíková, J., & Chytilová, J. (2022). C ommunicating doctors' consensus persistently increases covid-19 vaccinations. *Nature*, *606*(7914), 542–549.

BBC. (2009, April). How the hillsborough disaster happened. http://news.bbc.co.uk/1/hi/uk/7992845.stm

Begg, N. T., Gill, O., & White, J. M. (1989). Cover (cover of vaccination evaluated rapidly): Description of the england and wales scheme. *Public health*, *103*(2), 81–89.

Bursztyn, L., Rao, A., Roth, C. P., & Yanagizawa-Drott, D. H. (2020). *Misinformation during a pandemic* (tech. rep.). National Bureau of Economic Research.

Calvert, N., Ashton, J. R., & Garnett, E. (2013). Mumps outbreak in private schools: Public health lessons for the post-wakefield era. *The Lancet*, *381*(9878), 1625–1626.

Conn, D. (2017, February). Liverpool ban sun journalists over hillsborough coverage. https://www.theguardian.com/football/2017/feb/10/liverpool-ban-the-sun-newspaper-over-hillsborough-coverage

Deer, B. (2011). How the vaccine crisis was meant to make money. *Bmj*, *342*.

Foos, F., & Bischof, D. (2020). Tabloid media campaigns and public opinion: Quasi-experimental evidence on euroscepticism in england.

Gabis, L. V., Attia, O. L., Goldman, M., Barak, N., Tefera, P., Shefer, S., Shaham, M., & Lerman-Sagie, T. (2022). The myth of vaccination and autism spectrum. *European Journal of Paediatric Neurology*, *36*, 151–158.

Jansen, V. A., Stollenwerk, N., Jensen, H. J., Ramsay, M., Edmunds, W., & Rhodes, C. (2003). Measles outbreaks in a population with declining vaccine uptake. *Science*, *301*(5634), 804–804.

Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2013). Efficient estimation of word representations in vector space. *arXiv preprint arXiv:1301.3781*.

Mikolov, T., Sutskever, I., Chen, K., Corrado, G. S., & Dean, J. (2013). Distributed representations of words and phrases and their compositionality. *Advances in neural information processing systems*, *26*.

Mindell, J., Biddulph, J. P., Hirani, V., Stamatakis, E., Craig, R., Nunn, S., & Shelton, N. (2012). Cohort profile: The health survey for england. *International journal of epidemiology*, *41*(6), 1585–1593.

Motta, M., & Stecula, D. (2021). Quantifying the effect of wakefield et al.(1998) on skepticism about mmr vaccine safety in the us. *PloS one*, *16*(8), e0256395.

Olden, A., & Møen, J. (2022). The triple difference estimator. *The Econometrics Journal*, *25*(3), 531–553.

Organization, W. H., et al. (2019). Measles vaccines: Who position paper, april 2017–recommendations. *Vaccine*, *37*(2), 219–222.

Park, A., Bryson, C., & Curtis, J. (2014). *British social attitudes 31*. NatCen London.

Pennycook, G., & Rand, D. G. (2021). Examining false beliefs about voter fraud in the wake of the 2020 presidential election. *The Harvard Kennedy School Misinformation Review*.

Rambachan, A., & Roth, J. (2023). A more credible approach to parallel trends. *Review of Economic Studies*, *90*(5), 2555–2591.

Rehurek, R., & Sojka, P. (2011). Gensim–python framework for vector space modelling. *NLP Centre, Faculty of Informatics, Masaryk University, Brno, Czech Republic*, *3*(2).

Rocha, Y. M., de Moura, G. A., Desidério, G. A., de Oliveira, C. H., Lourenço, F. D., & de Figueiredo Nicolete, L. D. (2021). The impact of fake news on social media and its influence on health during the covid-19 pandemic: A systematic review. *Journal of Public Health*, 1–10.

Rough, E., Bunn, S., & Vagnoni, C. (2022, March). Uk vaccination policy [House of Commons Research Briefing, CBP-9076].

Taylor, B., Miller, E., Farrington, C., 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. *The Lancet*, *353*(9169), 2026–2029.

Thompson, S., Meyer, J. C., Burnett, R. J., & Campbell, S. M. (2023). Mitigating vaccine hesitancy and building trust to prevent future measles outbreaks in england. *Vaccines*, *11*(2), 288.

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., et al. (1998). Retracted: Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children.

A Appendix

A.1 Violations of Parallel Trends

In this section we implement the '*credible*' approach to parallel trends proposed by Rambachan and Roth, 2023. Sub-figures (a) and (b) show that the estimated treatment effect for the first period after the media scare (2000) is robust to allowing for large deviations from parallel trends, compared to what is observed in the pre-treatment period. For example, (b) shows that the effect remains significant for values of $\bar{M}$ up to around 4.5. This suggest that the statistical significance of the result is robust to allowing for violations of parallel trends up to four times as big as the maximum violation in the pre-treatment period.

A.2 Falsification Tests

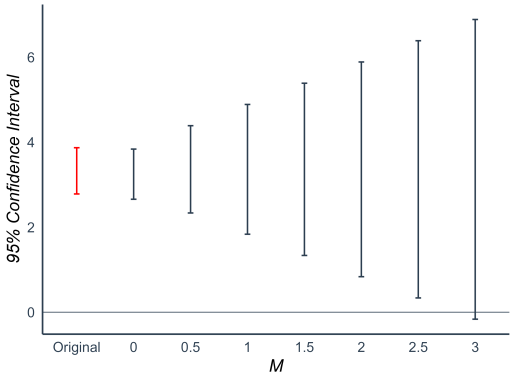
Table A.1 reports falsification tests. Equation 1 is estimated with health outcomes other than vaccination rates as independent variables. This exercise analyses the effect of being in Liverpool after the MMR media scare on other health outcomes. These health outcomes are constructed from the Health Survey for England (HSE). No statistically significant effects are detected on any of the health outcomes. Additionally the point estimates are not congruent in terms of direction. For example 'treatment' is estimated to increase the likelihood of smoking, while decreasing alcohol consumption; self reported general health is estimated to increase, but so is the likelihood of having a long term illness. Importantly for the results in Table 1 and 2, there is no estimated effect on GP registration. This is important as MMR vaccination occurs via appointments booked with GPs, so GP registration of parents is likely to be correlated to their propensity to vaccinate their children.

A.3 Spillovers to Other Vaccines and Triple Differences

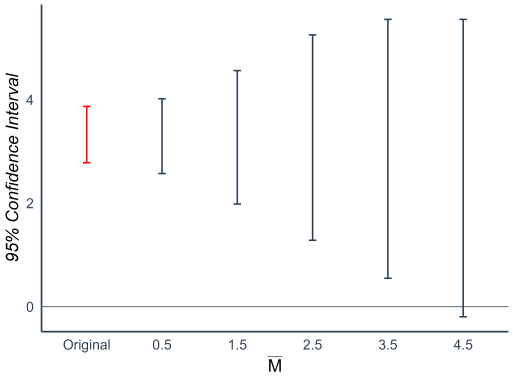
Previous research (Anderberg et al., 2011) has highlighted spillover effects of the MMR vaccine scare to hesitancy of other vaccines. Initially, the scare was specific to

Figure A.1: '*Credible*' Approach to Parallel Trends

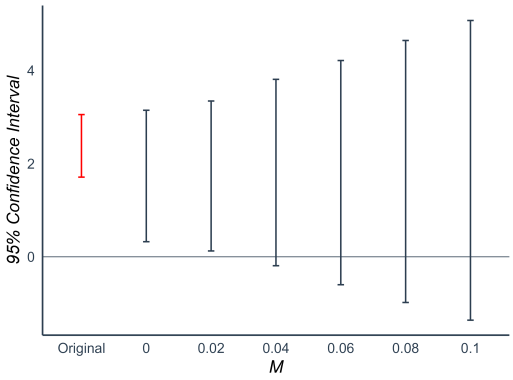
(a) SR; *Year = 2000*



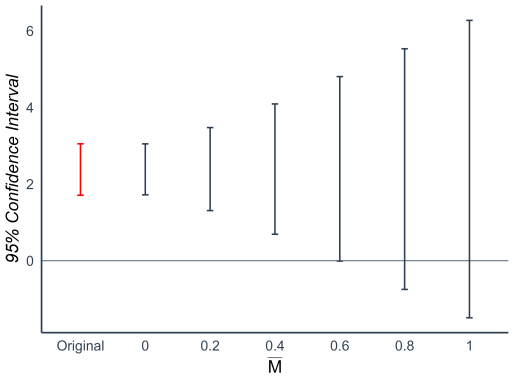
(b) RM; *Year = 2000*



(c) SR; Average Effect



(d) RM; Average Effect



Note: This figure plots the 95% confidence intervals, 'Original' are the estimates for the TWFE model outlined in Equation 1. (a) and (b) show the estimate only using the first post-treatment period (2000), while (c), and (d), average the effect from all post-treatment periods (2000-2008). (a) and (c) plot the 95% confidence intervals under the smoothness restriction as M varies. (b) and (d) plot the 95% confidence intervals for the relative magnitude as $\bar{M}$ varies.

Table A.1: Falsification Tests

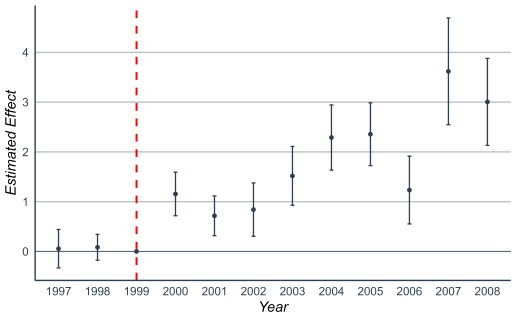
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Healthy BMI	Vitamin	General Health	Smoking	Alcohol	Long-term Ill	GP Reg
ATET	0.0254	-0.00902	0.0153	0.00482	-0.00848	0.00453	0.00382
	[0.0239]	[0.0377]	[0.0348]	[0.0446]	[0.0259]	[0.0278]	[0.00407]
Mean	0.363	0.265	0.776	0.330	0.284	0.403	0.992
N	591	587	591	591	591	591	587

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

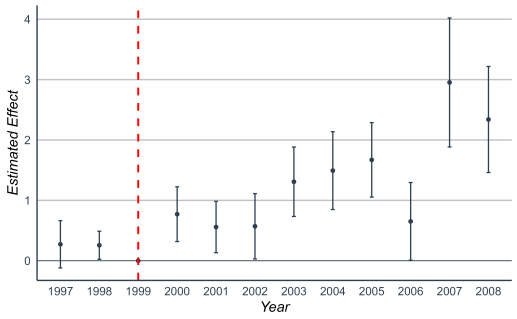
the combined MMR vaccine, with hesitant parents seeking three separate vaccines for Measles, Mumps, and Rubella. Over time, fears about the safety of vaccines generally spread. Figure A.2 shows event study plots for Hib and Polio 1st dose at 24 months. There is an effect of treatment (Liverpool Health Authority) immediately after the vaccine scare, however the effect is much smaller in magnitude than that for MMR. From 2003 onwards the treatment effects are more substantial.

Figure A.2: Event Study - Effect of Treatment (Liverpool) on vaccination rates at 24 months

(a) Haemophilus Influenzae Type B (Hib)



(b) Polio



Note: These figures plot event studies similar to Figure 8 with Hib (a), and Polio (b) vaccination rates at 24 months as the outcome variables.

The increasing treatment effects seen in Figure A.2 can be explained by parents becoming more hesitant to vaccinate their children generally (not just with the MMR specifically) overtime. The lack of readership of The Sun in Liverpool meant that parents here were less exposed to vaccine misinformation and therefore were less hesitant about other vaccines. This interpretation aligns with the fact that other vaccines were also reported on during the MMR scare. For example, Figure A.3 shows examples of articles from The Daily Mirror and The Sun reporting on the introduction of polio to the existing DTwP vaccine, to create a '5-in-1' vaccine. As in the begining of the vaccine scare, The Mirror reassures readers of the safety of vaccines, while The Sun highlights parents' fears.

Figure A.4 plots triple difference event studies. Here we take the difference between the first dose uptake rate of MMR and Hib (a), or Polio (b) at 24 months for the outcome variable in estimating Equation 2[7]. This lets us estimate the effect on MMR specifically, partialling out the effect of treatment on vaccine hesitancy generally. Given the spillovers to other vaccines, this can be thought of as a lower bound of the effect of the boycott during the media scare on MMR vaccination rates. As in Figure 8, Figure A.4 shows strong treatment effects in the years just after the media scare, as well as 2005, just after the Brian Deer documentary exposing the fraud in the Lancet paper linking MMR to autism.

A.4 The Sun Boycott Spillovers

A.5 Synthetic Difference-in-Differences

A.6 Additional Figures

[7]which is equivalent to estimating Equation 2 with both outcome variables and taking the differences in each estimated coefficient (Olden & Møen, 2022).

Figure A.3: Reporting on the 5-in-1 vaccine in The Daily Mirror and The Sun

***The Mirror**, 10th August, 2004*

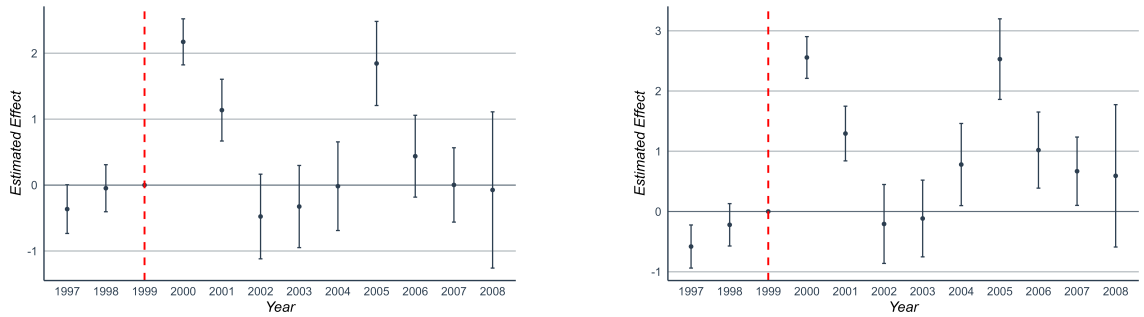
A NEW five-in-one vaccine for babies will worry some parents - and the public has every right to demand unbiased scientific information. But the scare stories surrounding MMR and the proposed new multiple-injection are a cynical attempt to exploit parental worries. Despite extensive research into the links between MMR and autism involving hundreds of thousands of children, no connection has ever been found. An injection almost identical to the new combined jab has been given to millions of children in Canada for the past seven years - and has an excellent safety record. And Dr. Andrew Wakefield's controversial study into MMR has been thoroughly discredited. Babies already receive DTwP, which protects against diphtheria, tetanus, whooping cough and Hib, a bacterial infection that can lead to meningitis. The added vaccine is polio - which most children already now receive orally. Bringing the five together will mean fewer ingredients, which means the new jab will be safer for children. The whooping cough vaccine has been improved - shown in studies to cause fewer sore arms and high temperatures. And the new polio vaccine should be even safer than the version in current use. Parents are always right to be concerned, especially when it comes to vaccines in children so young. But it is time to stop the scaremongering over MMR and other multiple vaccines - and to let the facts speak for themselves.

***The Sun**, 9th August, 2004*

A NEW compulsory five-in-one immunisation for babies was attacked by parents last night. The jab - protecting against diphtheria, tetanus, whooping cough, Hib, and polio - will be given at two months. It will begin in September, but is already meeting resistance. Opponents forecast a repeat of the chaos over the MMR jab, which protects against measles, mumps, and rubella. MMR has been linked to autism in children. Campaigner Jackie Fletcher said: "With five-in-one vaccines we would want to know what safety trials have taken place. How did they find out it was safe to do it in this combination?" A controversial mercury preservative is also to be removed from the whooping cough jab.

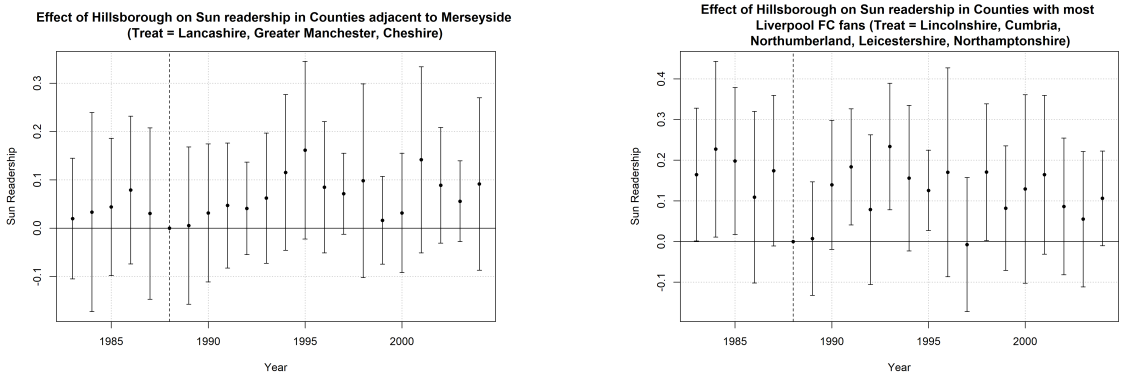
Figure A.4: Triple Differences - Effect of Treatment (Liverpool) on vaccination rates at 24 months

(a) *MMR - Hib* (b) *MMR - Polio*



Notes: This figure plots event studies similar to Figure 8. Here the outcome variables are the differences between vaccination rates at 24 months. (a) shows *MMR - Hib*, (b) *MMR - Polio*.

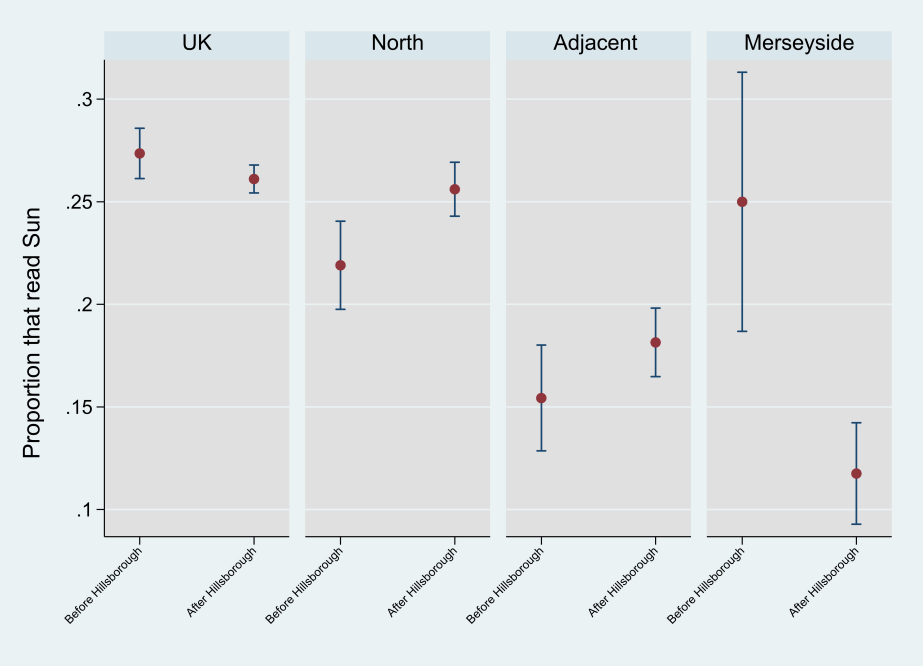
Figure A.5: No Evidence of Spillovers from The Sun Boycott



(a) Adjacent Counties (b) Liverpool FC Fans

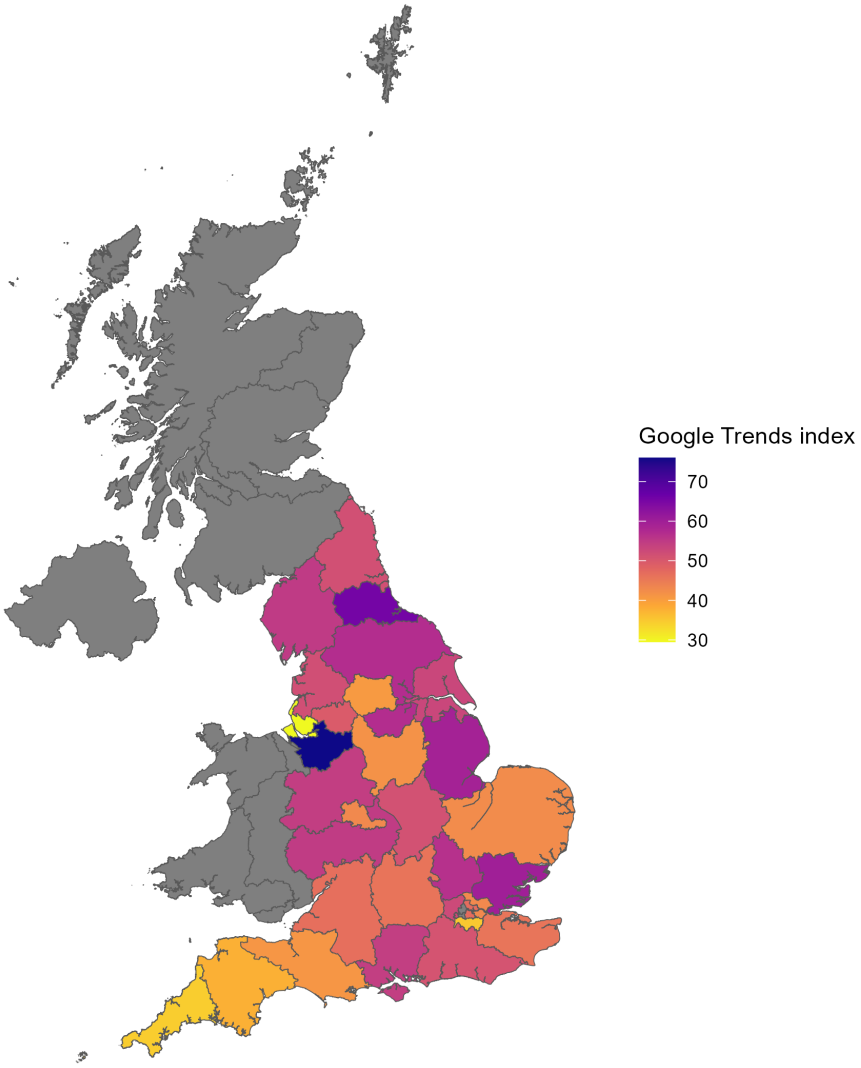
Note: This figure shows two event study plots where the outcome variable is the proportion of respondents to the British Social Attitudes Survey (BSA) that report reading The Sun as their main newspaper. In (a) treatment is equal to one for respondents in the counties adjacent to Merseyside. In (b) treatment is equal to one for counties which have the highest proportion of Liverpool FC supporters (less Merseyside). Respondents to the BSA before the 15th April (the date of the Hillsborough disaster) are moved to the pre-treatment period.

Figure A.6: Sun Readership in Different UK Regions



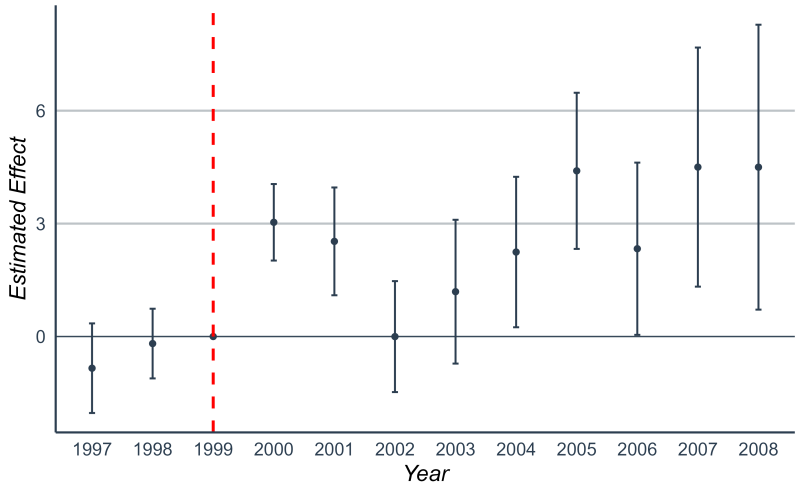
Note: This figure plots the means and 95% confidence intervals for respondents to the BSA that reported reading The Sun as their main newspaper. 'UK' includes all respondents, 'North' includes respondents from the north of England, 'Adjacent' includes those from counties adjacent to Merseyside (Cheshire, Greater Manchester, and Lancaster), and finally 'Merseyside' includes those in the county of Merseyside (which includes the city of Liverpool).

Figure A.7: Google Trends result for "The Sun" by county (2004 - 2024)



Note: This figure maps counties by relative number Google searches for "The Sun" from 2004 until February 2024. From the 198 towns/cities returned, Liverpool had the second lowest index for searches of "The Sun".

Figure A.8: Effect of Treatment (Liverpool) on MMR Vaccination at 24 months old (Only Urban areas as control)



Note: This figure plots an event study similar to Figure 8, in which all Health Authorities which do not contain a city have been removed from the control group.

Table A.2: Demographic Characteristics and Health Outcomes in Liverpool and England

	(1) England		(2) Liverpool		T-test Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
White	78539	0.868	707	0.895	-0.027**
		(0.001)		(0.012)	
Age	78539	38.862	707	38.737	0.125
		(0.081)		(0.895)	
HH Income	65833	26498.501	545	19728.697	6769.804***
		(91.405)		(781.220)	
A Level	61453	0.369	552	0.326	0.042**
		(0.002)		(0.020)	
Healthy BMI	73908	0.383	663	0.412	-0.029
		(0.002)		(0.019)	
Registered with GP	78539	0.991	707	0.993	-0.002
		(0.000)		(0.003)	

Notes: White is a binary variable equal to one if the respondent is coded as having a white ethnicity, zero otherwise. Age is the average age of the respondents in years. HH Income is average annual household income of the respondents in pounds. A Level is a binary variable equal to one if the respondent has achieved an Advanced Level qualification or higher. Healthy BMI is a binary variable equal to one if the respondent's Body Mass Index (BMI) falls within the healthy range. Registered with GP is a binary variable equal to one if the respondent is registered with a General Practitioner (GP). The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.