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Covid and the coalfield: Covid-19 vaccine hesitance in Wales and Appalachia

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ABSTRACT

Background: Vaccine hesitancy is a barrier to Covid-19 vaccine uptake and displays a social gradient, compounding health disparities. While social gradients are a vital concept in health, they flatten distinctions between types of disadvantaged community. This paper focuses on vaccine hesitance in post-industrial and de-industrialising coalfields. The social consequences of the decline of coal mining may present barriers to vaccine uptake.

Methods: We ran parallel surveys in Wales (N = 4187) and US states overlapping with central Appalachia (N = 4864), to examine whether vaccine attitudes and uptake varied between areas with different coal mining histories. These surveys were accompanied by qualitative interviews of 36 residents of these coalfields to explore vaccination decisions and triangulate with survey data.

Results: Factor analysis identified four axes of attitudes in the survey data: *vaccine confidence*, *covid scepticism*, *vaccine individualism*, and *concerned confusion*. These themes were echoed in the interviews. Vaccine confidence was lower; and covid scepticism, vaccine individualism, and concerned confusion higher, in residents of areas of Wales with greater mining extent and where pits closed during certain periods. Residents of former US coal counties had lower vaccine confidence and higher covid scepticism, while those in current coal counties had greater vaccine individualism and concerned confusion. In former US coal counties and Welsh areas where pits closed since 1980, vaccine uptake was lower. Differences could not be explained by respondents' income and education. In the interviews, norms of social solidarity were often invoked by vaccinated respondents, while unvaccinated respondents did not frame decisions in the context of the industrial history of their areas.

Discussion: The legacy of coal-mining's decline presents barriers to public health campaigns. We show evidence of this across two historically significant coalfields. Attention is needed to avert negative public health consequences of global energy transition.

1. Introduction

As the public health truism goes, 'vaccines do not save lives, vaccinations save lives.' In countries with ample supply of COVID-19 vaccines, vaccine hesitancy is a major barrier to uptake. Even pre-COVID, the World Health Organisation listed vaccination hesitancy as one of the top ten threats to public health globally (World Health Organisation, 2019). Uptake of vaccines follows a social gradient, with lower uptake in

disadvantaged communities than in more affluent ones (Perry et al., 2021; Saban et al., 2021), compounding existing health disparities (Arceo-Gomez et al., 2022; Kontopantelis et al., 2021). Thus, understanding barriers to vaccination in disadvantaged communities is a priority.

While social gradients are a key concept in health, they can obscure distinctions between different types of disadvantaged communities. Different communities have their own histories, politics, and contexts,

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and there is value in examining them on these terms. This paper examines one such type of disadvantaged community: post-industrial and de-industrialising coalfield communities, specifically those in Wales, in the United Kingdom (UK), and Central Appalachia, in the United States (US). These coalfields share a similar industrial history which has shaped them economically, socially, and culturally. These factors may also apply, or will apply following the energy transition, to coalfields elsewhere in the world.

Coalfield communities are home to substantial proportions of the populations of historically industrialised countries. The Coalfields Regeneration Trust estimates that just under 9% of the population of Britain lives on a coalfield, while [Esposito and Abramson \(2021\)](#) report that a third of European NUTS2 regions, statistical geographic units with a population between 0.8 and 3 million, contain a coalfield. Twenty-one US states produced coal in 2021 ([U.S. Energy Information Administration \(EIA\), \(2022\)](#)). Coal mining is labour-intensive, and population centres grew around these keystone employers. The challenges to public health on coalfields affect millions of people.

2. The Welsh coalfields

Wales has two coalfields: one in the South Wales Valleys, among the UK's largest, and a smaller one in northeast Wales. It is difficult to exaggerate the historical importance of coal mining to Wales. Welsh coal powered the British industrial revolution, and demand for coal, in turn, drove Wales' industrialisation. The 1921 UK Census records that a third of the Welsh male workforce worked in the coal mining industry ([Hudson and Beynon, 2021](#)). Raymond Williams described industrial South Wales as one of Wales' "two truths," and the coalfield is a national heartland, shaping the way that Wales sees itself and is seen ([Williams, 1985](#)).

After World War Two, the industry was nationalised, but a combination of cheaper imports and an adversarial relationship between the UK Government and the coal mining unions led to the winding down of domestic coal production. By the early 2010s, coal mining had almost entirely ceased in Wales. This had a devastating socioeconomic impact on the South Wales Valleys, and former mining communities are among Wales' most deprived communities today ([Welsh Government, 2014](#)). The experience of de-industrialisation, including the year-long miners' strike of 1984-5, has left a difficult relationship with the UK state ([Hudson and Beynon, 2021](#)).

3. The Appalachian coalfield

Appalachia, a region running from Pennsylvania to Alabama, contains the Appalachian Basin, which supplied the majority of US coal for much of the 20th century. Coal mining remains economically important in Appalachia but has declined from its former peak, especially in Central Appalachia ([Bowen et al., 2018](#)), with profound effects on the region. Appalachia, previously Democratic-leaning, has realigned towards the Republicans, partly due to the political economy of coal ([Lewin, 2019](#)). Coal mining remains an important part of the region's identity, celebrated in music and popular culture ([Lilly, 2010](#)), but the industry's decline is also often implicated in the region's challenges, including the opioid epidemic ([Eichenlaub and Nasher, 2021](#)). Like in Wales, Appalachia's coalmining heritage continues to shape both its destiny and sense of itself.

4. COVID and the coalfield

These experiences of extractive capitalism and deindustrialisation may have led, understandably, to lower trust in authorities. Several studies have identified lower levels of social trust on coalfields, either in general ([Abreu and Jones, 2021](#); [Saville, 2019](#)), or specifically following industrial disasters ([Scott et al., 2016](#)). Indeed, low social trust forms part of a stigmatising stereotype of Appalachia's people ([Scott and](#)

[McSpirit, 2014](#)). In the context of the COVID-19 response, trust has been shown to be vital ([Saville and Thomas, 2022](#)), so vaccination campaigns on coalfields may face barriers to success. Conversely, coalfield regions have enduring norms of social solidarity ([Beynon et al., 2021](#)), which may inform vaccination decisions in the opposite direction. Where COVID-19 vaccination is framed as an act of social solidarity, this might especially resonate in these communities where solidarity is culturally valorised ([Phillips, 2018](#)).

The present study applies a mixed methods design to a) assess the extent to which the coal mining history of Wales and the states overlapping with central Appalachia is associated with COVID-19 vaccine hesitancy using large-scale quantitative surveys and b) explore how residents of these areas approached vaccination decisions in detailed qualitative interviews. By triangulating these two methodologies across two countries, we aim to provide a rigorous and holistic picture of the challenges facing COVID-19 vaccination campaigns and public health more broadly in this class of community.

5. Methods

5.1. Permissions

This project was approved by the School of Psychology and Sports Science ethics committee at Bangor University.

6. Quantitative surveys

6.1. Fieldwork

Fieldwork for both surveys was carried out in December 2021 by YouGov in Wales and Response: AI in the US.

6.2. Wales

We aimed for a sample of 3500 respondents, representative of the 18+ population of Wales, plus a 500-person non-representative 'boost' sample, from middle super output areas (MSOAs; a unit of UK Census geography with populations of ~8000) with coalmines until at least 1960 (see below for details of geographic data). YouGov recruited from their participant panel, who signed up to be invited to surveys in exchange for points to be redeemed for cash. The representative sample was quota-sampled using age, sex, and education (and their interactions); social grade; political attention; region; party membership; 2019 general election vote; and the 2016 EU referendum vote. The boost sample was invited without demographic quota from panel members in MSOAs with post-1960 coal mining. Data from respondents who responded in suspicious patterns (e.g. 'straightlining', completing very quickly), or with internet provider addresses associated with survey fraud were removed.

6.3. Appalachia

Response: AI recruited 4864 respondents, 1210 from coalfield counties (see below) and 3654 from non-coalfield counties in Kentucky, Virginia, West Virginia, Tennessee, and Ohio (Central Appalachia). Respondents were recruited to be representative of coalfield and non-coalfield counties of these states on age, gender, race, income, and education, but coalfield counties were over-sampled for statistical power. Recruitment combined three survey modes: 3560 from Lucid Marketplace, a panel of prospective survey participants rewarded with cash or shopping vouchers. 1190 using geodemographically targeted advertisements on Meta, and 61 using live-interviewer random-digit telephone survey. Data from respondents giving suspicious response patterns (e.g. 'straightlining', completing very quickly), or whose internet provider addresses were associated with survey fraud were removed.

6.4. Geographical data

6.4.1. Wales

Survey data were linked to geographical data for respondents' MSOA of residence. The coalmining history of each MSOA was determined using two sources of data. Firstly, the UK Coal Authority provided shapefiles of coalmine workings for Wales. These were overlaid with MSOA boundaries using the *sf* package for R. The proportion of each MSOA's area with underground mineworks was computed to give the *mining extent*. Secondly, the Northern Mine Research Society kindly shared a database of post-1946 (when the industry was largely nationalised) mine closures in Wales, including longitude, latitudes, and year of closure, which were linked to specific MSOAs using the *sf* package for R and MSOA boundaries. MSOAs were categorised into four categories: MSOAs with no history of mining (according to mining extent data), MSOAs where all pits closed before 1960, MSOAs where all pits closed 1960–1979, and MSOAs with pits that closed after 1979. As described below, separate models were fitted for the Welsh data using the two operationalisations of coalfield status. See Fig. 1 for maps.

6.5. US

Coal production data by county between 1983 and 2020 (the period available) were accessed from the US Energy Information Administration website. Counties recording coal production were classified as coalfield counties. The Appalachian Regional Commission's definition was used to classify counties as Appalachian or non-Appalachian, and Appalachian coal counties were oversampled.

Counties were subsequently classified into three groups: *currently-producing counties*, which produced coal in 2020, the most recent available year ($n_{\text{counties}} = 52$, $n_{\text{respondents}} = 439$); *formerly producing counties*, which were not currently producing coal but had in the 1983–2019 period ($n_{\text{counties}} = 67$, $n_{\text{respondents}} = 737$); and *non-coal counties*, with no coal production in this period ($n_{\text{counties}} = 344$, $n_{\text{respondents}} = 3688$). See Fig. 2 for a map.

6.6. Measures

The survey questionnaire contained items on attitudes towards COVID-19 and vaccinations against it; vaccination status; trust; information sources on COVID-19; social capital and belonging; economic circumstances; and voting history, not all of which are reported here.

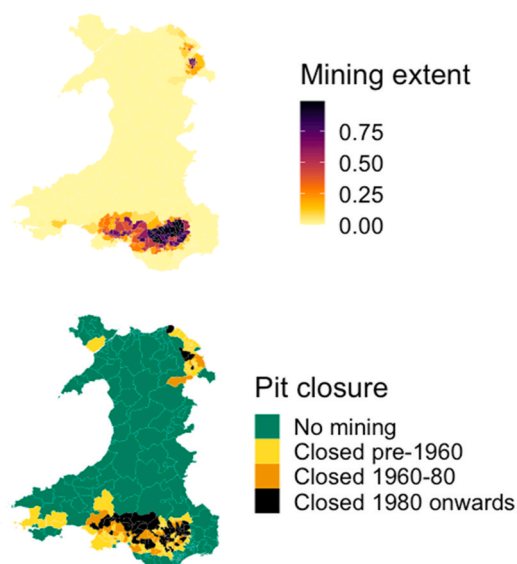


Fig. 1. Mining extent and pit closure period for all Welsh MSOAs.

Attitudes towards COVID-19 and vaccination were assessed using a battery of statements, which respondents rated their agreement on a five-point likert scale from 'Strongly agree' to 'Strongly disagree.' The statements were: "People have a responsibility to their community to get vaccinated," "I feel confused by all the contradictory information I hear about COVID-19," "Vaccination should be a matter of personal choice," "The COVID-19 pandemic was deliberately planned," "Being vaccinated makes you much less likely to get seriously ill from COVID," "The government is exaggerating the seriousness of COVID-19," "I trust the science behind the COVID-19 vaccines," "COVID-19 is a serious health threat," and "The risks of COVID-19 disease are greater than the risks of the vaccine". Some items were taken from the COVID-VAC scale (El-Mohandes et al., 2021), and some were developed by the current authors.

Vaccination status was assessed with the item "Have you received a COVID-19 vaccine?", with the response options: "Yes, I've had at least two doses of a vaccine," "Yes, I've had a single dose of a vaccine," "No," and "Prefer not to answer."

6.7. Analysis

All analyses were run using R (R Core Team, 2019).

Vaccination status was scored 1 for respondents reporting receiving the full original course of the vaccine (two doses or one dose of the Johnson and Johnson vaccine) and 0 for participants reporting no or partial vaccination.

Responses to the nine statements about COVID were converted into numeric data (Strongly disagree = 1, strongly agree = 5, etc.) and factor analysed to reduce their dimensionality. Data from the two countries were combined and a parallel scree test was run. Exploratory factor analysis with oblimin rotation was then run, again on the two datasets together, retaining as many factors as indicated by the parallel scree.

The relationship between coalmining history of area of residence, attitudes about COVID-19, and vaccination status were measured using a series of generalised linear mixed effects models. Models were fitted separately for Wales and the US. Mining extent in Wales was z-scored, based on a mean of 0.199 and a standard deviation of 0.303. The models for Wales were run for both mining extent and for the four pit closure categories described above.

Firstly, a binomial generalised linear mixed effects model was fitted to assess whether scores on each factor predicted vaccination. Here scores from the factor analysis were included as fixed effects (separate models for each factor) and MSOA (Wales) or county, nested within state (US), were included as random intercepts.

Secondly, linear mixed-effects models were fitted to assess how the attitudinal factors varied between respondents from areas with different mining histories. Three models were fitted for each factor in each country. A) crude models predicting scores on the relevant factor (separate models for each factor) with mining extent (Wales, z-scored), pit closure category (Wales, categorical) or mining status (US, categorical) as the only fixed effect and MSOA (Wales) or county nested within state (US), as a random intercept. B) demographically adjusted models: as crude models but also adjusting for gender, age, ethnicity (Wales), race, and Hispanic ethnicity (last two US) as fixed effects. C) socio-demographically adjusted models: as demographically adjusted models but adding income band and education.

Thirdly, binomial generalised linear mixed effects models were used to compare vaccine uptake between respondents from areas with different coalmining history. As above, crude, demographically adjusted, and sociodemographically adjusted models were fitted, but with vaccination status as the dependent variable instead of attitudinal factors. Again, in Wales, models were fitted separately using mining extent and pit closure data.

Given that the mining history of areas likely has a causal effect on their socio-demographic make-up, it is plausible that the demographically and socio-demographically adjusted models condition on mediators of any causal effect, underestimating said effect. However, it is

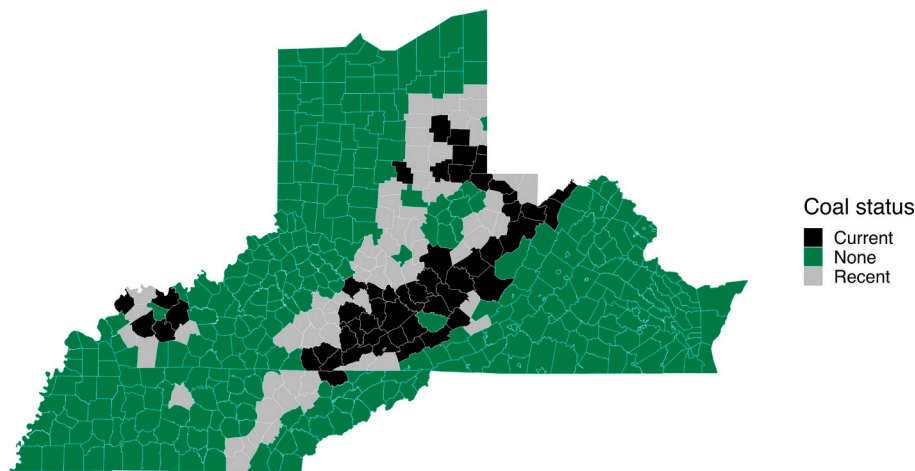


Fig. 2. Coal status by US county in the surveyed states.

nonetheless informative to assess whether any attitudinal or behavioural differences between groups can be accounted for socio-demographically.

7. Results

7.1. Sample characteristics

Table 1 gives information on the two survey samples. In Wales, the realised sample was 4187, and analyses are based on 4011 respondents who responded to all attitudinal items and the vaccination item. In the US, reported analyses were based on 4833 respondents who responded to all attitudinal items and the vaccination item.

7.2. Factor analysis of attitudinal questions

The parallel scree test suggested that four factors were needed. Table 2 presents the loadings of each item onto each factor.

The first factor, which we call *vaccine confidence*, loads on items pertaining to the effectiveness, necessity, and trustworthiness of vaccination against COVID, but also positively on the item about the seriousness of COVID and negatively on the item about the pandemic being deliberately planned. The second factor, *COVID scepticism*, loads on items expressing scepticism about the seriousness of COVID-19 or advancing alternative narratives of the pandemic. The third factor, *vaccine individualism*, primarily loads on items around autonomy and responsibility in vaccination decisions, with smaller loadings on items expressing mistrust in vaccination and governmental response to the pandemic. The fourth factor, *confused concern*, loads positively on items expressing confusion with contradictory information and the view that the pandemic was planned, but also on items describing COVID as a serious health threat and vaccination being less of a threat than the virus.

Vaccine confidence was strongly negatively associated with COVID scepticism ($r = -0.64$) and vaccine individualism ($r = -0.59$), and weakly positively correlated with confused concern ($r = 0.15$). COVID scepticism was positively associated with vaccine individualism ($r = 0.58$) and very weakly associated with confused concern ($r = 0.08$). Vaccine individualism and confused concern were very weakly positively associated ($r = 0.07$).

7.3. Attitudes as predictors of vaccination

A standard deviation increase in vaccine confidence was associated with increased odds of vaccination (Wales: OR = 5.02, $CI_{95\%} = 4.28-5.89$; US: OR = 5.32, $CI_{95\%} = 4.79-5.91$). Conversely, a standard

deviation increase in covid scepticism was associated with lower odds of vaccination (Wales: OR = 0.28, $CI_{95\%} = 0.25-0.32$; US: OR = 0.39, $CI_{95\%} = 0.36-0.42$) and a standard deviation increase in vaccine individualism was associated with reduced odds of vaccination (Wales: OR = 0.17, $CI_{95\%} = 0.14-0.20$; US: OR = 0.23, $CI_{95\%} = 0.21-0.25$). Confused concern was not associated with vaccination odds (Wales: OR = 1.04, $CI_{95\%} = 0.93-1.18$; US: OR = 1.02, $CI_{95\%} = 0.96-1.09$).

7.4. Coalmining history as a predictor of vaccination attitudes

Tables 3–5 and Fig. 3 presents results of the models examining how attitudes varied as a function of coalmining history of respondents' area of residence.

Vaccine confidence was lower in areas of Wales with greater mining extent, an association which survived adjustment for socio-demographic factors. When using the pit closure measure, respondents living in MSOAs where pits closed either prior to 1960 or after 1980 had lower vaccine confidence than non-mining MSOAs. MSOAs where pits closed 1960–1979 were equivalent to non-mining MSOAs. These analyses were robust to adjustment. In the US, former coal counties had lower vaccine confidence than non-mining counties, while currently producing counties did not differ from non-mining counties. Again, these associations were robust to adjustment for socio-demographic factors.

COVID scepticism was higher in Welsh MSOAs with greater mining extent, with and without adjustment. Again, respondents from MSOAs with pre-1960 or post-1979 pit closures were more COVID sceptical than those from non-mining MSOAs, with and without adjustment. In the US, formerly producing counties had higher COVID scepticism scores, while currently producing counties did not, which again survived adjustment.

Vaccine individualism was again higher in Welsh MSOAs with greater history of coalmining, even accounting for socio-demographics. Likewise, respondents in MSOAs with pre-1960 or post-1979 pit closures had greater vaccine individualism than respondents from non-mining MSOAs, with and without adjustment. In the US, this time *currently* producing counties had higher scores. This did not survive adjustment though.

Confused concern was again positively associated with mining extent in Wales, which survived adjustment. Using pit closure, respondents from all coalmining categories expressed greater confused concern than those from non-mining MSOAs, before and after adjustment. In the US, currently producing counties had higher scores, which survived adjustment.

7.5. Coalmining history as a predictor of vaccine uptake

Table 6 and Fig. 4 show odds ratios from the models examining

Table 1

Composition of the two survey samples by coalfield status. Welsh sample presented broken down by both coalfield exposures.

Wales (mining extent)				United States				Wales (pit closure)				
Mining extent quantile	No mining	Quantile 1	Quantile 2	Coal status	None	Current	Recent	Pit Closure	No mining	Closed pre-1960	Closed 1960-79	Closed post-1979
Sample size	2098	975	944	Sample size	3669	431	733	Sample size	2094	827	447	643
Age (mean (SD))	51.92 (17.17)	53.94 (15.97)	51.27 (15.73)	Age (mean (SD))	46.78 (16.70)	45.74 (16.07)	44.75 (15.90)	Age (mean (SD))	51.94 (17.16)	52.45 (16.33)	52.32 (15.99)	53.12 (15.26)
Ethnicity (%)				Race (%)				Ethnicity (%)				
Asian	21 (1.0)	3 (0.3)	6 (0.6)	White/ Caucasian	2896 (78.9)	331 (76.8)	657 (89.6)	Asian	20 (1.0)	4 (0.5)	3 (0.7)	2 (0.3)
Black	6 (0.3)	1 (0.1)	2 (0.2)	Arab/Middle Eastern	5 (0.1)	4 (0.9)	1 (0.1)	Black	6 (0.3)	2 (0.2)	0 (0.0)	1 (0.2)
Mixed	27 (1.3)	4 (0.4)	2 (0.2)	Asian or Pacific Islander	82 (2.2)	8 (1.9)	16 (2.2)	Mixed	27 (1.3)	3 (0.4)	1 (0.2)	2 (0.3)
Other	3 (0.1)	0 (0.0)	2 (0.2)	Black/ African- American	587 (16.0)	85 (19.7)	51 (7.0)	Other	3 (0.1)	1 (0.1)	0 (0.0)	1 (0.2)
White Welsh, English, British etc.	1980 (94.4)	950 (97.4)	919 (97.4)	Native American	35 (1.0)	1 (0.2)	2 (0.3)	White Welsh, English, British etc.	1977 (94.4)	807 (97.6)	433 (96.9)	627 (97.5)
White Other	61 (2.9)	17 (1.7)	13 (1.4)	Other/mixed race	64 (1.7)	2 (0.5)	6 (0.8)	White Other	61 (2.9)	10 (1.2)	10 (2.2)	10 (1.6)
Household income (%)				Hispanic (%)	200 (5.5)	18 (4.2)	24 (3.3)	Household income (%)				
Under £5000 per year	41 (2.0)	16 (1.6)	19 (2.0)	Household income (%)				Under £5000 per year	41 (2.0)	19 (2.3)	5 (1.1)	11 (1.7)
£5000 to £9999 per year	78 (3.7)	45 (4.6)	39 (4.1)	Less than \$10,000	232 (6.3)	37 (8.6)	43 (5.9)	£5000 to £9999 per year	78 (3.7)	42 (5.1)	23 (5.1)	19 (3.0)
£10,000 to £14,999 per year	180 (8.6)	68 (7.0)	74 (7.8)	\$10,001 - \$20,000	308 (8.4)	49 (11.4)	65 (8.9)	£10,000 to £14,999 per year	180 (8.6)	51 (6.2)	37 (8.3)	54 (8.4)
£15,000 to £19,999 per year	174 (8.3)	88 (9.0)	82 (8.7)	\$20,001 - \$30,000	424 (11.6)	50 (11.6)	69 (9.4)	£15,000 to £19,999 per year	174 (8.3)	69 (8.3)	41 (9.2)	60 (9.3)
£20,000 to £24,999 per year	181 (8.6)	108 (11.1)	81 (8.6)	\$30,001 - \$40,000	381 (10.4)	29 (6.7)	57 (7.8)	£20,000 to £24,999 per year	181 (8.6)	81 (9.8)	35 (7.8)	73 (11.4)
£25,000 to £29,999 per year	179 (8.5)	87 (8.9)	75 (7.9)	\$40,001 - \$50,000	310 (8.4)	31 (7.2)	56 (7.6)	£25,000 to £29,999 per year	179 (8.5)	65 (7.9)	34 (7.6)	63 (9.8)
£30,000 to £34,999 per year	128 (6.1)	58 (5.9)	82 (8.7)	\$50,001 - \$75,000	606 (16.5)	55 (12.8)	100 (13.6)	£30,000 to £34,999 per year	128 (6.1)	52 (6.3)	36 (8.1)	51 (7.9)
£35,000 to £39,999 per year	130 (6.2)	59 (6.1)	62 (6.6)	\$75,001 - \$100,000	622 (17.0)	101 (23.4)	185 (25.2)	£35,000 to £39,999 per year	130 (6.2)	55 (6.7)	29 (6.5)	36 (5.6)
£40,000 to £44,999 per year	103 (4.9)	47 (4.8)	48 (5.1)	\$100,001 - \$150,000	633 (17.3)	62 (14.4)	143 (19.5)	£40,000 to £44,999 per year	103 (4.9)	43 (5.2)	27 (6.0)	25 (3.9)
£45,000 to £49,999 per year	89 (4.2)	39 (4.0)	35 (3.7)	\$150,001 or more	153 (4.2)	17 (3.9)	15 (2.0)	£45,000 to £49,999 per year	89 (4.3)	34 (4.1)	17 (3.8)	23 (3.6)
£50,000 to £59,999 per year	118 (5.6)	49 (5.0)	65 (6.9)					£50,000 to £59,999 per year	118 (5.6)	47 (5.7)	21 (4.7)	46 (7.2)
£60,000 to £69,999 per year	89 (4.2)	40 (4.1)	38 (4.0)					£60,000 to £69,999 per year	89 (4.3)	33 (4.0)	22 (4.9)	23 (3.6)
£70,000 to £99,999 per year	110 (5.2)	42 (4.3)	42 (4.4)					£70,000 to £99,999 per year	110 (5.3)	31 (3.7)	27 (6.0)	26 (4.0)
£100,000 and over	44 (2.1)	18 (1.8)	11 (1.2)					£100,000 and over	44 (2.1)	12 (1.5)	6 (1.3)	11 (1.7)
Don't know	110 (5.2)	41 (4.2)	30 (3.2)					Don't know	109 (5.2)	33 (4.0)	15 (3.4)	23 (3.6)
Prefer not to answer	344 (16.4)	170 (17.4)	161 (17.1)					Prefer not to answer	341 (16.3)	160 (19.3)	72 (16.1)	99 (15.4)
Education (%)				Education (%)				Education (%)				
None	106 (5.1)	52 (5.3)	72 (7.6)	Less than high school	26 (0.7)	12 (2.8)	9 (1.2)	None	106 (5.1)	52 (6.3)	24 (5.4)	48 (7.5)
Non-degree qualification	1211 (57.7)	563 (57.7)	536 (56.8)	High school incomplete	209 (5.7)	66 (15.3)	68 (9.3)	Non-degree qualification	1209 (57.7)	501 (60.6)	246 (55.0)	350 (54.4)

(continued on next page)

Table 1 (continued)

Wales (mining extent)				United States				Wales (pit closure)				
Mining extent quantile	No mining	Quantile 1	Quantile 2	Coal status	None	Current	Recent	Pit Closure	No mining	Closed pre-1960	Closed 1960-79	Closed post-1979
University Degree	710 (33.8)	326 (33.4)	303 (32.1)	High school graduate	1164 (31.7)	160 (37.1)	333 (45.4)	University Degree	710 (33.9)	242 (29.3)	157 (35.1)	230 (35.8)
Unknown	71 (3.4)	34 (3.5)	33 (3.5)	Some college, no degree	956 (26.1)	109 (25.3)	155 (21.1)	Unknown	69 (3.3)	32 (3.9)	20 (4.5)	15 (2.3)
				2-year associate degree, college or university	428 (11.7)	32 (7.4)	52 (7.1)					
				4-year college or university degree/ Bachelor's degree	562 (15.3)	30 (7.0)	80 (10.9)					
				Postgraduate or professional schooling (no postgraduate degree)	58 (1.6)	6 (1.4)	3 (0.4)					
				Postgraduate or professional degree	266 (7.2)	16 (3.7)	33 (4.5)					
Fully vaccinated (%)	93%	92%	91%	Fully vaccinated (%)	67%	70%	58%	Fully vaccinated (%)	93%	91%	94%	91%
Vaccine confidence (mean (SD))	0.07 (0.96)	-0.04 (1.04)	-0.11 (1.04)	Vaccine confidence (mean (SD))	0.05 (1.02)	0.02 (0.86)	-0.22 (0.95)	Vaccine confidence (mean (SD))	0.07 (0.95)	-0.11 (1.08)	0.03 (0.93)	-0.10 (1.05)
Covid scepticism (mean (SD))	-0.05 (0.97)	0.01 (1.03)	0.09 (1.02)	Covid scepticism (mean (SD))	-0.06 (1.03)	0.13 (0.83)	0.20 (0.93)	Covid scepticism (mean (SD))	-0.05 (0.97)	0.08 (1.06)	0.00 (1.00)	0.05 (1.00)
Covid individualism (mean (SD))	-0.05 (0.98)	0.01 (1.02)	0.10 (1.02)	Covid individualism (mean (SD))	-0.03 (1.03)	0.14 (0.88)	0.04 (0.93)	Covid individualism (mean (SD))	-0.05 (0.98)	0.07 (1.05)	0.03 (0.96)	0.04 (1.03)
Confused concern (mean (SD))	-0.06 (0.98)	0.04 (1.01)	0.09 (1.02)	Confused concern (mean (SD))	-0.05 (0.99)	0.43 (0.98)	-0.03 (0.99)	Confused concern (mean (SD))	-0.06 (0.98)	0.08 (1.06)	0.08 (1.00)	0.05 (0.98)

vaccine uptake's association with mining history and Table 1 gives absolute vaccination rates for respondents in each category of area. In Wales, vaccination rates did not vary as a function of mining extent in any model. When using pit closure, however, for respondents from MSOAs where pits closed after 1979, the odds of being vaccinated were only 70% of those from non-mining MSOAs (90.5% vs 93.1%), which became slightly stronger after adjustment. Those from MSOAs with pre-1960 pit closures had lower vaccination rates in the adjusted models (91.1%). Confidence intervals overlapped with 1 in the unadjusted model, although this was marginal.

In the US, the odds of vaccination in formerly producing counties were approximately 65% of non-mining counties (58.4% vs 66.9%), which survived adjustment. Rates in currently producing (69.6%) and non-mining counties were similar.

7.6. Post-hoc analyses

In response to a reviewer's comment, we reran our sociodemographic models, adjusting for political partisanship to test whether our findings could be explained by the mediating effects of political partisanship. In Wales, we used the item "If there were a general election held tomorrow, which party would you vote for?" with the response options: "Conservative," "Labour," "Liberal Democrat," "Scottish National Party (SNP)," "Plaid Cymru," "Reform UK," "Green," "Some other party," "Would not vote," "Don't know," and "Prefer not to answer." In the US, we used the item: "In the 2020 Presidential election, did you vote for?" with the response options: "Joe Biden," "Donald Trump," "Someone else," and "I didn't vote."

In both the Welsh and US data, the reported associations between

coalfield status and the four COVID attitude factors or vaccine uptake survived this adjustment. Indeed, this adjustment made very little difference to the magnitude of the associations (although vote choice was an independent predictor of these outcomes, especially in the US data), see [Supplementary Table A](#).

7.7. Qualitative interviews

7.7.1. Methods

To explore the reasons underlying these results, we conducted qualitative interviews with 36 participants, aiming for similar numbers of vaccinated and unvaccinated interviewees from coalfield areas of both countries.

Participants were recruited using paid advertisements on Meta. Advertisements were geographically targeted to Appalachian coal counties, and to the South Wales coalfield using the 'drop pin' option. The advertisements directed prospective participants to a screening form, asking their name, email, UK post code/US county, work status, and vaccination status; and when would be convenient to be interviewed. After checking that they met inclusion criteria, our interviewers (ABC and SG) emailed prospective participants to give further information, answer questions, and schedule interviews. Interviews were conducted using video conferencing software and lasted between 45 min and 2 h.

An explanatory, sequential, mixed method design ([Creswell, 2014](#)) was adopted whereby results identified in the survey were followed up as themes in the qualitative interviews. Interviews were semi-structured using a topic guide covering six areas, corresponding to the survey topics: (i) place, belonging and participation; (ii) work and employment, (iii) impact of the COVID-19 pandemic; (iv) vaccine attitudes and

Table 2

Loadings of each attitudinal item on each of the four factors.

	Factor 1	Factor 2	Factor 3	Factor 4
	Vaccine confidence	Covid scepticism	Vaccine individualism	Confused concern
"People have a responsibility to their community to get vaccinated"	0.43	-0.04	-0.50	0.16
"I feel confused by all the contradictory information I hear about Covid-19"	-0.12	0.18	0.10	0.33
"Vaccination should be a matter of personal choice"	0.02	0.10	0.71	0.06
"The COVID-19 pandemic was deliberately planned"	-0.46	0.23	0.02	0.39
"Being vaccinated makes you much less likely to get seriously ill from Covid"	0.84	0.05	0.0	-0.02
"The government is exaggerating the seriousness of COVID-19"	0.04	0.85	0.11	0.08
"I trust the science behind the COVID-19 vaccines"	0.72	-0.04	-0.14	-0.03
"COVID-19 is a serious health threat"	0.3	-0.55	0.06	0.28
"The risks of COVID-19 disease are greater than the risks of the vaccine"	0.63	-0.15	-0.02	0.12

experiences, (v) trust and information, and (vi) political attitudes. Topics consisted of several opening questions which interviewers would follow up on. Interviews were carried out in January to March of 2022, and were audio-recorded and transcribed, before identifying information was redacted.

The final sample comprised twelve fully vaccinated, eight unvaccinated, and one single-dosed participant from Wales and ten fully vaccinated and five unvaccinated participants from Appalachia. Our interviewers encountered higher non-response to emails amongst unvaccinated potential participants, particularly in Appalachia.

Participants were fairly balanced in terms of sex (21 female, 15 male) and aged between their late twenties and late seventies. Of five unvaccinated interviewees in Appalachia, one was working full-time and three were looking for work or unable to work for health reasons. In Wales, of eight unvaccinated respondents, four worked full-time, two part-time, two were unemployed and one had retired. In both areas, vaccinated participants were either working full-time or retired.

We adopted a holistic approach to analysis, considering the sample as a whole, across the two countries and across vaccinated and unvaccinated participants. Our reasoning was that the attitudes of vaccinated and unvaccinated interviewees may not be clearly opposed to each other, and we should be sensitive to continuities in views across sets of participants. Furthermore, a sample with a range of vaccination statuses meant we could examine the complex relationship between hesitancy, scepticism, and uptake.

For this paper, the qualitative data were explored for content reflecting the four factors identified by the factor analysis of the survey data. Quotes and other content which contextualized and further

developed the ideas suggested by the factors were identified, as was content which contested or challenged these themes. We also used the qualitative data to explore the extent to which our interviewees made sense of their decisions and experiences through the lens of their regions' industrial histories or whether any such putative effects of this history on vaccine hesitance were implicit rather than explicit.

8. Results

8.1. Vaccine confidence

Most vaccinated respondents expressed very little hesitancy or concern about getting vaccinated. These participants' responses were commonly characterized by short, self-evident statements as to their reasons for getting vaccinated and a tendency towards dismissiveness when asked about any concerns. Interviewees described the decision as a "no-brainer" and "couldn't see why not." These responses were more common in Wales, but some interviewees from Appalachia gave similar responses, one referring to getting vaccinated "without question" and another saying that she "never gave it a second thought."

This self-evident reasoning appeared less common among interviewees who reported health problems. One vaccinated interviewee from Wales with underlying health conditions cited some concern over risks but concluded she "would rather be vaccinated than be in that bed with a ventilator" and was "happy to go." This perspective points to hints of hesitancy which are evident in a minority of vaccinated cases. Another vaccinated Welsh interviewee with an underlying health condition provides a good illustration of this:

"I don't know if I was convinced. Yes, I trusted it. Trusted it as much as they could be trusted. I mean, I'm [in my 60s], I'm not a youngster. Perhaps down the line, there may be an enduring side effect. Who knows? I don't know. Nobody knows. We're allowed to have doubts, aren't we?"

In this extract, the interviewee's age and health inform his decision, as he compares himself to 'a youngster' whose reasoning might be different. This speaks to a broader theme in the qualitative data around how individual justifications are not made abstractly but in relation to personal and social contexts and predicaments. In Appalachia, concerns over getting vaccinated were also reported. One vaccinated interviewee described conflicting emotions following vaccination, being 'scared' at first, followed by relief at being protected:

"I was nervous because some of my friends who had gone before me, had gotten pretty sick and had a fever and didn't feel well for a few days. So I was a little nervous and some of them had no side effects whatsoever so I just wasn't sure what to expect. But it was okay and then when I went there it was a little bit scary because the police and the National Guard and people were there to help line up cars, as there was a different type of situation than I've ever seen before. Like when I got my other vaccines there were no police, no National Guard there, you know, it was just going to a regular doctor's appointment, this was different and it felt different."

Here she expresses strong feelings of nervousness. The way in which her attention was drawn to the state's involvement – police, national guard – unlike her previous experiences of going for other vaccines appears significant, given that mistrust of government was a reason for many not getting vaccinated. We illustrate the significance of this in more detail below.

Reasons given by unvaccinated interviewees for not getting vaccinated included insufficient testing and that the rollout had been rushed. An unvaccinated Welsh interviewee stated: "I don't think that they know enough to have invented something, reliably safe, in the time period." Similarly, an unvaccinated Appalachian interviewee said:

"I don't feel like they had enough time to study this, to do research, in order to come up with this vaccine, I think they were rushed into it, and

Table 3
Coefficients of models predicting Covid attitudes in Wales using mining extent. Bold typeface indicates terms of interest.

Model	Term	Vaccine confidence			Covid scepticism			Vaccine individualism			Confused concern		
		Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%
Unadjusted	Mining extent (z-scored)	-0.07	-0.11	-0.04	0.06	0.02	0.09	0.06	0.03	0.09	0.06	0.03	0.09
Demographically adjusted	Mining extent (z-scored)	-0.07	-0.10	-0.03	0.05	0.02	0.08	0.05	0.02	0.08	0.06	0.03	0.09
	Gender - Female	-0.09	-0.15	-0.03	-0.05	-0.11	0.01	0.09	0.03	0.15	0.12	0.06	0.19
	Age	0.01	0.01	0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00
	Ethnicity - Black	-0.22	-0.96	0.51	0.20	-0.53	0.93	0.17	-0.55	0.90	0.48	-0.26	1.22
	Ethnicity - Mixed	-0.28	-0.77	0.21	0.46	-0.03	0.95	0.44	-0.04	0.93	0.17	-0.33	0.67
	Ethnicity - Other	0.30	-0.63	1.23	0.36	-0.57	1.29	0.00	-0.92	0.91	0.11	-0.83	1.05
	Ethnicity - White Welsh, English, British etc.	-0.12	-0.48	0.24	0.30	-0.06	0.66	0.11	-0.24	0.47	0.20	-0.17	0.56
	Ethnicity - White Other	-0.16	-0.57	0.25	0.37	-0.04	0.78	0.10	-0.30	0.51	0.03	-0.39	0.45
Sociodemographically adjusted	Mining extent (z-scored)	-0.06	-0.09	-0.03	0.04	0.01	0.08	0.05	0.02	0.08	0.05	0.02	0.08
	Gender - Female	-0.05	-0.11	0.01	-0.07	-0.13	-0.01	0.07	0.01	0.13	0.09	0.03	0.15
	Age	0.01	0.01	0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	0.00	0.00	0.00
	Ethnicity - Black	-0.31	-1.03	0.40	0.28	-0.44	1.00	0.22	-0.50	0.94	0.61	-0.11	1.34
	Ethnicity - Mixed	-0.27	-0.74	0.21	0.44	-0.04	0.92	0.43	-0.05	0.91	0.14	-0.34	0.63
	Ethnicity - Other	0.43	-0.48	1.33	0.24	-0.68	1.15	-0.04	-0.95	0.87	0.03	-0.90	0.95
	Ethnicity - White Welsh, English, British etc.	-0.14	-0.49	0.21	0.29	-0.06	0.65	0.11	-0.24	0.46	0.21	-0.14	0.57
	Ethnicity - White Other	-0.20	-0.60	0.20	0.37	-0.03	0.78	0.10	-0.30	0.50	0.05	-0.35	0.46
	Household income - £5000 to £9999 per year	0.24	-0.02	0.50	-0.25	-0.52	0.01	-0.10	-0.37	0.16	-0.06	-0.33	0.20
	Household income - £10,000 to £14,999 per year	0.21	-0.03	0.45	-0.16	-0.40	0.09	-0.05	-0.29	0.20	0.10	-0.15	0.34
	Household income - £15,000 to £19,999 per year	0.17	-0.07	0.41	-0.08	-0.32	0.16	0.00	-0.24	0.24	-0.08	-0.32	0.16
	Household income - £20,000 to £24,999 per year	0.42	0.18	0.65	-0.28	-0.52	-0.04	-0.21	-0.45	0.02	-0.17	-0.41	0.08
	Household income - £25,000 to £29,999 per year	0.41	0.17	0.65	-0.27	-0.51	-0.03	-0.16	-0.40	0.08	-0.08	-0.32	0.16
	Household income - £30,000 to £34,999 per year	0.38	0.14	0.63	-0.20	-0.44	0.05	-0.20	-0.44	0.05	-0.07	-0.32	0.18
	Household income - £35,000 to £39,999 per year	0.31	0.07	0.56	-0.21	-0.46	0.04	-0.11	-0.36	0.14	-0.04	-0.29	0.21
	Household income - £40,000 to £44,999 per year	0.42	0.17	0.68	-0.20	-0.46	0.05	-0.14	-0.40	0.11	-0.07	-0.32	0.19
	Household income - £45,000 to £49,999 per year	0.44	0.18	0.70	-0.33	-0.59	-0.07	-0.16	-0.42	0.10	-0.29	-0.56	-0.03
	Household income - £50,000 to £59,999 per year	0.54	0.29	0.79	-0.29	-0.54	-0.04	-0.23	-0.49	0.02	-0.24	-0.49	0.02
	Household income - £60,000 to £69,999 per year	0.59	0.33	0.85	-0.34	-0.61	-0.08	-0.28	-0.54	-0.01	-0.17	-0.44	0.09
	Household income - £70,000 to £99,999 per year	0.53	0.28	0.79	-0.31	-0.56	-0.05	-0.30	-0.56	-0.04	-0.35	-0.61	-0.09
	Household income - £100,000 and over	0.48	0.17	0.78	-0.21	-0.52	0.10	-0.24	-0.55	0.07	-0.35	-0.66	-0.04
	Household income - Don't know	0.32	0.06	0.57	-0.27	-0.53	-0.01	-0.27	-0.53	-0.01	-0.11	-0.37	0.15
	Household income - Prefer not to answer	0.29	0.06	0.52	-0.19	-0.42	0.04	-0.16	-0.39	0.07	-0.06	-0.29	0.17
	Education - None	-0.17	-0.31	-0.04	0.10	-0.03	0.23	0.06	-0.07	0.19	0.29	0.16	0.43
	Education - University Degree	0.34	0.28	0.41	-0.32	-0.38	-0.25	-0.17	-0.23	-0.10	-0.33	-0.40	-0.26
	Education - Unknown	-0.33	-0.50	-0.17	0.21	0.05	0.38	0.19	0.02	0.35	0.27	0.10	0.44

Table 4
Coefficients of models predicting Covid attitudes in Wales using pit closure.

Model	Term	Vaccine confidence			Covid scepticism			Vaccine individualism			Confused concern		
		Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%
Unadjusted	Mine closure pre-1960	-0.18	-0.27	-0.09	0.13	0.04	0.21	0.13	0.04	0.21	0.14	0.06	0.23
	Mine closure 1960–1979	-0.06	-0.17	0.06	0.06	-0.05	0.16	0.09	-0.02	0.20	0.15	0.04	0.26
	Mine closure 1980 onwards	-0.18	-0.28	-0.08	0.11	0.01	0.20	0.10	0.00	0.19	0.12	0.02	0.21
Demographically adjusted	Mine closure pre-1960	-0.19	-0.28	-0.10	0.13	0.05	0.22	0.14	0.06	0.22	0.14	0.05	0.22
	Mine closure 1960–1979	-0.06	-0.17	0.06	0.06	-0.04	0.17	0.10	-0.01	0.20	0.14	0.03	0.25
	Mine closure 1980 onwards	-0.19	-0.29	-0.09	0.12	0.03	0.21	0.12	0.02	0.21	0.10	0.00	0.20
Sociodemographically adjusted	Gender - Female	-0.09	-0.15	-0.03	-0.05	-0.11	0.01	0.09	0.03	0.15	0.13	0.06	0.19
	Age	0.01	0.01	0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00
	Ethnicity - Black	-0.21	-0.95	0.52	0.20	-0.54	0.93	0.17	-0.55	0.89	0.48	-0.26	1.23
	Ethnicity - Mixed	-0.28	-0.77	0.21	0.46	-0.03	0.95	0.44	-0.04	0.93	0.17	-0.33	0.66
	Ethnicity - Other	0.32	-0.61	1.25	0.36	-0.57	1.28	-0.01	-0.92	0.91	0.11	-0.83	1.05
	Ethnicity - White Welsh, English, British etc.	-0.11	-0.47	0.25	0.29	-0.07	0.65	0.10	-0.25	0.45	0.19	-0.18	0.55
	Ethnicity - White Other	-0.16	-0.57	0.25	0.36	-0.05	0.77	0.10	-0.31	0.50	0.02	-0.39	0.44
	Mine closure pre-1960	-0.17	-0.25	-0.08	0.11	0.04	0.19	0.13	0.05	0.21	0.12	0.03	0.20
	Mine closure 1960–1979	-0.05	-0.16	0.06	0.06	-0.04	0.16	0.09	-0.01	0.19	0.14	0.03	0.24
	Mine closure 1980 onwards	-0.20	-0.29	-0.10	0.13	0.04	0.22	0.12	0.03	0.21	0.10	0.01	0.19
	Gender - Female	-0.05	-0.11	0.01	-0.07	-0.13	-0.01	0.07	0.01	0.13	0.09	0.03	0.15
	Age	0.01	0.01	0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	0.00	0.00	0.00
	Ethnicity - Black	-0.31	-1.02	0.41	0.27	-0.45	0.99	0.22	-0.50	0.94	0.62	-0.11	1.34
	Ethnicity - Mixed	-0.27	-0.74	0.21	0.44	-0.04	0.92	0.43	-0.05	0.91	0.14	-0.34	0.63
	Ethnicity - Other	0.45	-0.46	1.35	0.23	-0.69	1.14	-0.05	-0.96	0.86	0.03	-0.89	0.95
	Ethnicity - White Welsh, English, British etc.	-0.13	-0.48	0.22	0.28	-0.07	0.64	0.10	-0.26	0.45	0.20	-0.15	0.56
	Ethnicity - White Other	-0.20	-0.60	0.20	0.37	-0.03	0.77	0.09	-0.31	0.50	0.05	-0.36	0.45
	Household income - £5000 to £9999 per year	0.23	-0.03	0.49	-0.25	-0.51	0.01	-0.10	-0.36	0.16	-0.06	-0.33	0.20
	Household income - £10,000 to £14,999 per year	0.20	-0.04	0.44	-0.15	-0.39	0.09	-0.04	-0.28	0.20	0.10	-0.14	0.35
	Household income - £15,000 to £19,999 per year	0.16	-0.07	0.40	-0.08	-0.32	0.16	0.00	-0.24	0.24	-0.08	-0.32	0.16
	Household income - £20,000 to £24,999 per year	0.41	0.18	0.65	-0.28	-0.52	-0.04	-0.22	-0.45	0.02	-0.17	-0.41	0.07
	Household income - £25,000 to £29,999 per year	0.41	0.17	0.65	-0.26	-0.50	-0.02	-0.15	-0.39	0.09	-0.08	-0.32	0.17
	Household income - £30,000 to £34,999 per year	0.37	0.12	0.61	-0.19	-0.43	0.06	-0.19	-0.43	0.06	-0.07	-0.32	0.18
	Household income - £35,000 to £39,999 per year	0.30	0.06	0.55	-0.21	-0.45	0.04	-0.11	-0.36	0.14	-0.03	-0.29	0.22
	Household income - £40,000 to £44,999 per year	0.42	0.16	0.67	-0.20	-0.46	0.06	-0.14	-0.39	0.12	-0.07	-0.32	0.19
	Household income - £45,000 to £49,999 per year	0.43	0.17	0.69	-0.33	-0.59	-0.06	-0.16	-0.42	0.10	-0.29	-0.56	-0.03
	Household income - £50,000 to £59,999 per year	0.53	0.28	0.78	-0.29	-0.54	-0.03	-0.23	-0.48	0.02	-0.23	-0.48	0.02
	Household income - £60,000 to £69,999 per year	0.58	0.32	0.84	-0.34	-0.60	-0.08	-0.27	-0.54	-0.01	-0.17	-0.44	0.09
	Household income - £70,000 to £99,999 per year	0.52	0.26	0.78	-0.30	-0.56	-0.04	-0.29	-0.55	-0.04	-0.35	-0.61	-0.09
	Household income - £100,000 and over	0.47	0.16	0.78	-0.21	-0.52	0.10	-0.24	-0.55	0.07	-0.35	-0.66	-0.04
	Household income - Don't know	0.31	0.05	0.57	-0.26	-0.52	0.00	-0.27	-0.52	-0.01	-0.11	-0.37	0.15
	Household income - Prefer not to answer	0.29	0.06	0.51	-0.18	-0.41	0.05	-0.15	-0.38	0.07	-0.06	-0.29	0.17
	Education - None	-0.17	-0.30	-0.04	0.10	-0.03	0.23	0.06	-0.07	0.19	0.30	0.16	0.43
	Education - University Degree	0.34	0.28	0.41	-0.32	-0.39	-0.25	-0.17	-0.24	-0.10	-0.33	-0.40	-0.26
	Education - Unknown	-0.34	-0.51	-0.17	0.22	0.05	0.38	0.19	0.02	0.35	0.27	0.10	0.44

Table 5
Coefficients of models predicting Covid attitudes in the US using coal status.

Model	Term	Vaccine confidence			Covid scepticism			Vaccine individualism			Confused concern		
		Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%	Coefficient	CI 2.5%	CI 97.5%
Unadjusted	Coal status - Current	−0.04	−0.18	0.10	0.13	−0.01	0.26	0.14	0.01	0.28	0.31	0.17	0.46
Demographically adjusted	Coal status - Recent	−0.20	−0.32	−0.09	0.18	0.07	0.30	0.08	−0.03	0.19	−0.01	−0.13	0.11
	Coal status - Current	−0.02	−0.15	0.12	0.09	−0.04	0.22	0.12	−0.01	0.25	0.31	0.16	0.46
	Coal status - Recent	−0.18	−0.30	−0.07	0.14	0.03	0.25	0.07	−0.04	0.18	0.00	−0.13	0.12
	Race - Arab/Middle Eastern	0.29	−0.31	0.89	−0.24	−0.83	0.36	−0.47	−1.08	0.13	0.44	−0.16	1.05
	Race - Asian or Pacific Islander	−0.02	−0.21	0.17	0.06	−0.13	0.25	−0.29	−0.48	−0.10	0.00	−0.19	0.19
	Race - Black/African-American	−0.06	−0.14	0.03	0.08	0.00	0.17	−0.01	−0.09	0.07	0.19	0.11	0.28
	Race - Native American	0.01	−0.30	0.32	−0.19	−0.50	0.12	−0.26	−0.58	0.05	0.06	−0.25	0.37
	Race - Other/mixed race	−0.14	−0.37	0.09	−0.02	−0.25	0.21	0.27	0.04	0.50	−0.01	−0.24	0.22
	Hispanic	0.07	−0.06	0.19	−0.07	−0.20	0.06	−0.26	−0.39	−0.13	−0.15	−0.28	−0.02
Sociodemographically adjusted	Gender - Female	−0.05	−0.11	0.01	−0.25	−0.31	−0.20	0.15	0.10	0.21	−0.01	−0.07	0.04
	Age	0.01	0.01	0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	0.00	0.00	0.00
	Coal status - Current	0.05	−0.08	0.18	0.07	−0.05	0.19	0.09	−0.04	0.22	0.31	0.17	0.46
	Coal status - Recent	−0.15	−0.26	−0.05	0.11	0.01	0.21	0.04	−0.06	0.14	−0.03	−0.15	0.09
	Race - Arab/Middle Eastern	0.40	−0.18	0.99	−0.29	−0.87	0.30	−0.53	−1.12	0.07	0.46	−0.14	1.05
	Race - Asian or Pacific Islander	0.06	−0.13	0.25	−0.01	−0.20	0.18	−0.25	−0.44	−0.06	0.04	−0.15	0.23
	Race - Black/African-American	0.00	−0.09	0.08	0.03	−0.06	0.11	−0.06	−0.15	0.02	0.14	0.06	0.23
	Race - Native American	0.01	−0.29	0.31	−0.19	−0.49	0.11	−0.27	−0.58	0.04	0.03	−0.27	0.34
	Race - Other/mixed race	−0.16	−0.39	0.06	0.02	−0.20	0.24	0.28	0.05	0.50	0.01	−0.22	0.23
	Hispanic	0.04	−0.08	0.17	−0.06	−0.19	0.07	−0.26	−0.39	−0.13	−0.14	−0.27	−0.01
	Gender - Female	−0.08	−0.14	−0.02	−0.18	−0.24	−0.12	0.12	0.06	0.18	−0.02	−0.08	0.05
	Age	0.01	0.01	0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	0.00	0.00	0.00
	Income - \$10,001 - \$20,000	−0.01	−0.15	0.13	0.01	−0.12	0.15	0.02	−0.12	0.16	−0.04	−0.18	0.10
	Income - \$20,001 - \$30,000	0.07	−0.06	0.20	−0.01	−0.14	0.12	−0.11	−0.25	0.02	−0.10	−0.24	0.03
	Income - \$30,001 - \$40,000	0.08	−0.06	0.22	−0.04	−0.18	0.09	−0.05	−0.19	0.09	−0.10	−0.24	0.04
	Income - \$40,001 - \$50,000	0.01	−0.13	0.15	0.14	0.00	0.28	0.00	−0.15	0.15	−0.05	−0.20	0.09
	Income - \$50,001 - \$75,000	0.05	−0.08	0.18	0.04	−0.08	0.17	−0.09	−0.22	0.05	−0.11	−0.24	0.02
	Income - \$75,001 - \$100,000	0.07	−0.06	0.20	0.18	0.05	0.31	−0.06	−0.19	0.08	0.00	−0.13	0.13
	Income - \$100,001 - \$150,000	0.08	−0.05	0.21	0.17	0.04	0.30	−0.22	−0.35	−0.08	−0.05	−0.18	0.09
	Income - \$150,001 or more	0.19	0.01	0.37	−0.09	−0.27	0.09	−0.25	−0.43	−0.06	−0.11	−0.29	0.08
	Education - High school incomplete	−0.15	−0.44	0.13	−0.17	−0.46	0.12	−0.26	−0.56	0.03	−0.56	−0.86	−0.27
	Education - High school graduate	0.11	−0.17	0.38	−0.06	−0.33	0.22	−0.09	−0.37	0.19	−0.03	−0.31	0.25
	Education - Some college, no degree	0.26	−0.01	0.54	−0.27	−0.55	0.00	−0.16	−0.44	0.12	−0.17	−0.45	0.11
	Education - 2-year associate degree, college or university	0.25	−0.03	0.54	−0.25	−0.53	0.04	−0.21	−0.50	0.08	−0.22	−0.51	0.07
	Education - 4-year college or university degree/ Bachelor's degree	0.60	0.31	0.88	−0.55	−0.83	−0.26	−0.47	−0.76	−0.18	−0.40	−0.69	−0.11
	Education - Postgraduate or professional schooling (no postgraduate degree)	0.64	0.28	0.99	−0.56	−0.91	−0.21	−0.50	−0.86	−0.14	−0.41	−0.77	−0.05
	Education - Postgraduate or professional degree	0.69	0.40	0.98	−0.68	−0.98	−0.39	−0.54	−0.84	−0.25	−0.62	−0.92	−0.32

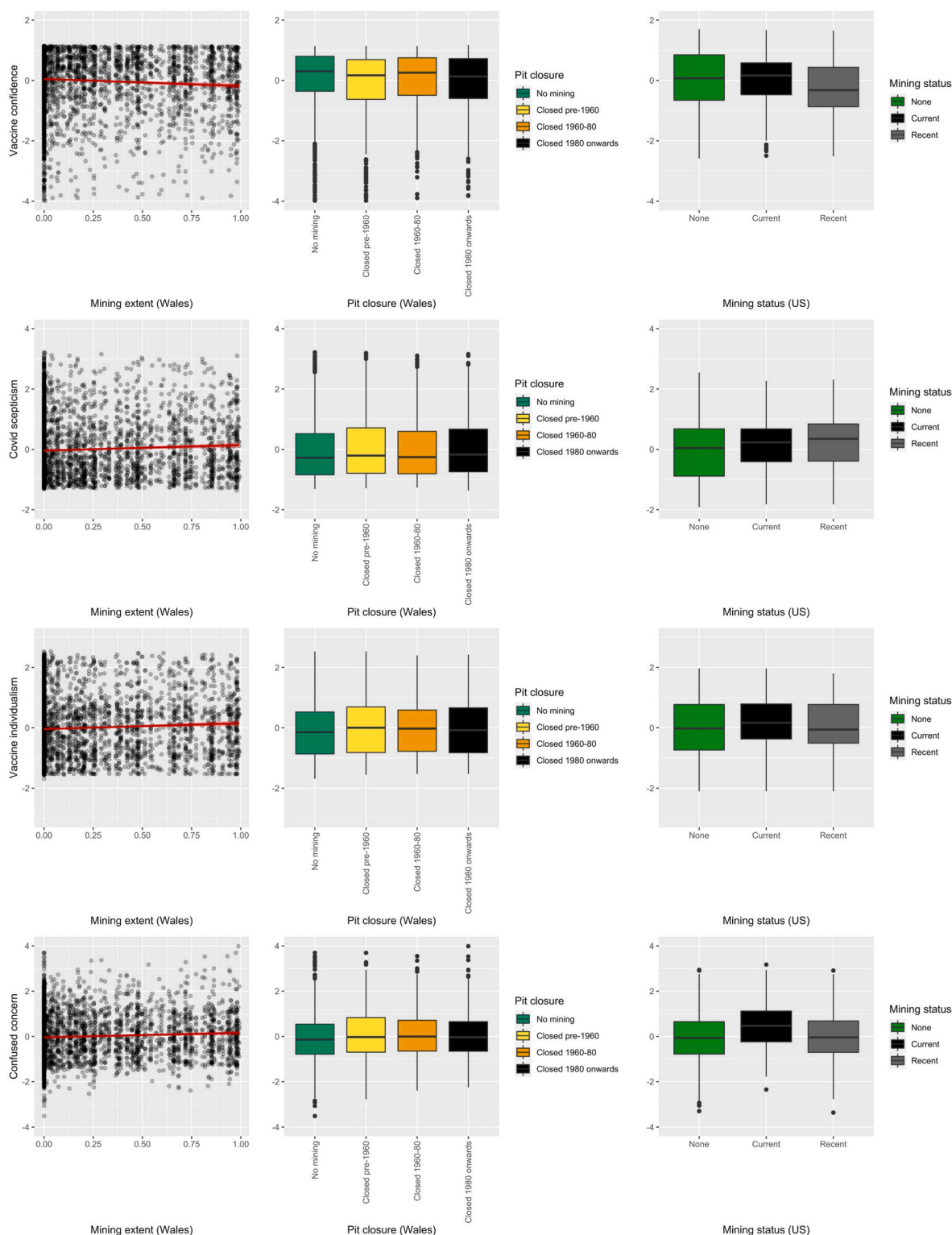


Fig. 3. Association between mining status (x-axis on all plots) and the four attitudinal factors (y-axes) for mining extent (left column) and pit closure (middle column) exposures in Wales, and mining status exposure in the US (right column).

they didn't study it and research it enough and they don't know what the side effects are going to be."

Others refer to people they know dying or getting seriously ill following vaccination. An unvaccinated interviewee in Wales referred to how someone he knew had to have a limb amputated after getting the vaccine. Another said:

"I know more people that have had adverse reactions to the vaccine and I know more people that have actually died from COVID after having the vaccines."

In between these more polarized positions, several interviewees report describing real dilemmas. One unvaccinated interviewee in Wales said she was *"wavering"* and *"still battling the decision."* While she was

Table 6

Odds ratios for models examining vaccination status as a function of coal history in Wales and the US.

	Association between vaccination status and coalfield exposure											
	Wales (Mining extent)				United States				Wales (Period of closure)			
	Term	OR	OR CI 2.5%	OR CI 97.5%	Term	OR	OR CI 2.5%	OR CI 97.5%	Term	OR	OR CI 2.5%	OR CI 97.5%
Unadjusted	Mining extent (z-scored)	0.94	0.84	1.05	Coal status - Current	1.06	0.76	1.46	Mine closure pre-1960	0.75	0.56	1.01
					Coal status - Recent	0.65	0.50	0.84	Mine closure 1960–1979	1.20	0.78	1.84
									Mine closure 1980 onwards	0.70	0.52	0.96
Demographically adjusted	Mining extent (z-scored)	0.94	0.84	1.05	Coal status - Current	1.13	0.82	1.56	Mine closure pre-1960	0.70	0.52	0.94
	Gender - Female	0.88	0.69	1.12	Coal status - Recent	0.63	0.49	0.83	Mine closure 1960–1979	1.12	0.72	1.73
	Age	1.04	1.03	1.04	Gender - Female	0.50	0.44	0.58	Mine closure 1980 onwards	0.62	0.45	0.86
	Ethnicity - Black	0.10	0.02	0.56	Age	1.03	1.03	1.04	Gender - Female	0.88	0.69	1.12
	Ethnicity - Mixed	1.56	0.37	6.65	Race - Arab/Middle Eastern	0.62	0.16	2.37	Age	1.04	1.03	1.05
	Ethnicity - Other	0.81	0.07	9.52	Race - Asian or Pacific Islander	2.01	1.19	3.38	Ethnicity - Black	0.10	0.02	0.59
	Ethnicity - White Welsh, English, British etc.	1.59	0.59	4.34	Race - Black/African-American	0.97	0.79	1.19	Ethnicity - Mixed	1.59	0.37	6.77
	Ethnicity - White Other	0.94	0.29	3.01	Race - Native American	1.26	0.57	2.82	Ethnicity - Other	0.85	0.07	9.85
					Race - Other/mixed race	0.63	0.37	1.06	Ethnicity - White Welsh, English, British etc.	1.69	0.62	4.62
					Hispanic - Yes	1.52	1.11	2.07	Ethnicity - White Other	0.94	0.29	3.04
Sociodemographically adjusted	Mining extent (z-scored)	0.94	0.84	1.06	Coal status - Current	1.28	0.94	1.73	Mine closure pre-1960	0.72	0.53	0.97
	Gender - Female	0.95	0.74	1.22	Coal status - Recent	0.66	0.51	0.85	Mine closure 1960–1979	1.08	0.69	1.68
	Age	1.04	1.04	1.05	Gender - Female	0.58	0.49	0.68	Mine closure 1980 onwards	0.60	0.43	0.83
	Ethnicity - Black	0.06	0.01	0.37	Age	1.03	1.02	1.03	Gender - Female	0.95	0.74	1.22
	Ethnicity - Mixed	1.60	0.35	7.27	Race - Arab/Middle Eastern	0.72	0.18	2.84	Age	1.04	1.04	1.05
	Ethnicity - Other	0.77	0.06	9.98	Race - Asian or Pacific Islander	1.74	1.03	2.95	Ethnicity - Black	0.06	0.01	0.39
	Ethnicity - White Welsh, English, British etc.	1.39	0.49	3.96	Race - Black/African-American	1.08	0.88	1.34	Ethnicity - Mixed	1.65	0.36	7.53
	Ethnicity - White Other	0.81	0.24	2.76	Race - Native American	1.35	0.60	3.06	Ethnicity - Other	0.80	0.06	10.18
	Household income - £5000 to £9999 per year	0.75	0.36	1.58	Race - Other/mixed race	0.62	0.36	1.07	Ethnicity - White Welsh, English, British etc.	1.47	0.51	4.21
	Household income - £10,000 to £14,999 per year	1.40	0.69	2.87	Hispanic - Yes	1.41	1.02	1.95	Ethnicity - White Other	0.82	0.24	2.78
	Household income - £15,000 to £19,999 per year	1.76	0.86	3.61	Income - \$10,001 - \$20,000	1.00	0.72	1.38	Household income - £5000 to £9999 per year	0.74	0.35	1.55
	Household income - £20,000 to £24,999 per year	2.43	1.16	5.07	Income - \$20,001 - \$30,000	1.15	0.84	1.57	Household income - £10,000 to £14,999 per year	1.38	0.67	2.82
	Household income - £25,000 to £29,999 per year	2.26	1.07	4.79	Income - \$30,001 - \$40,000	1.46	1.06	2.02	Household income - £15,000 to £19,999 per year	1.75	0.86	3.60

(continued on next page)

Table 6 (continued)

Association between vaccination status and coalfield exposure											
Wales (Mining extent)				United States				Wales (Period of closure)			
Term	OR	OR CI 2.5%	OR CI 97.5%	Term	OR	OR CI 2.5%	OR CI 97.5%	Term	OR	OR CI 2.5%	OR CI 97.5%
Household income - £30,000 to £34,999 per year	2.09	0.97	4.51	Income - \$40,001 - \$50,000	1.37	0.97	1.92	Household income - £20,000 to £24,999 per year	2.44	1.16	5.10
Household income - £35,000 to £39,999 per year	2.02	0.94	4.34	Income - \$50,001 - \$75,000	1.59	1.17	2.17	Household income - £25,000 to £29,999 per year	2.26	1.07	4.79
Household income - £40,000 to £44,999 per year	2.45	1.08	5.55	Income - \$75,001 - \$100,000	2.00	1.47	2.74	Household income - £30,000 to £34,999 per year	2.09	0.97	4.52
Household income - £45,000 to £49,999 per year	2.83	1.16	6.89	Income - \$100,001 - \$150,000	2.29	1.67	3.15	Household income - £35,000 to £39,999 per year	2.01	0.93	4.31
Household income - £50,000 to £59,999 per year	6.01	2.28	15.86	Income - \$150,001 or more	2.79	1.68	4.64	Household income - £40,000 to £44,999 per year	2.43	1.07	5.51
Household income - £60,000 to £69,999 per year	5.96	2.13	16.70	Education - High school incomplete	1.24	0.60	2.54	Household income - £45,000 to £49,999 per year	2.83	1.16	6.91
Household income - £70,000 to £99,999 per year	4.17	1.67	10.42	Education - High school graduate	0.78	0.40	1.55	Household income - £50,000 to £59,999 per year	6.09	2.31	16.06
Household income - £100,000 and over	1.26	0.49	3.23	Education - Some college, no degree	1.12	0.56	2.22	Household income - £60,000 to £69,999 per year	5.82	2.08	16.28
Household income - Don't know	1.74	0.82	3.67	Education - 2-year associate degree, college or university	1.07	0.53	2.17	Household income - £70,000 to £99,999 per year	4.08	1.63	10.22
Household income - Prefer not to answer	2.15	1.09	4.26	Education - 4-year college or university degree/Bachelor's degree	2.11	1.04	4.28	Household income - £100,000 and over	1.24	0.48	3.17
Education - None	0.71	0.44	1.15	Education - Postgraduate or professional schooling (no postgraduate degree)	1.78	0.70	4.49	Household income - Don't know	1.72	0.81	3.63
Education - University Degree	1.89	1.40	2.56	Education - Postgraduate or professional degree	3.16	1.47	6.80	Household income - Prefer not to answer	2.14	1.08	4.24
Education - Unknown	0.94	0.54	1.65					Education - None	0.74	0.46	1.19
								Education - University Degree	1.89	1.40	2.55
								Education - Unknown	0.93	0.53	1.63

sceptical of the safety of the vaccines, not being vaccinated meant that she was not able to visit her family.

9. COVID scepticism

As well as discussing their confidence or hesitance in the safety and

efficacy of the vaccines, some respondents expressed a wider suspicion of official narratives about COVID, echoing the COVID scepticism factor identified in the survey data. Such views were often rooted in a broader lack of trust in government and mainstream media. In some cases, these exhibit some conspiratorial features based on alternative theories around the origin and spread of COVID-19 and the vested interests

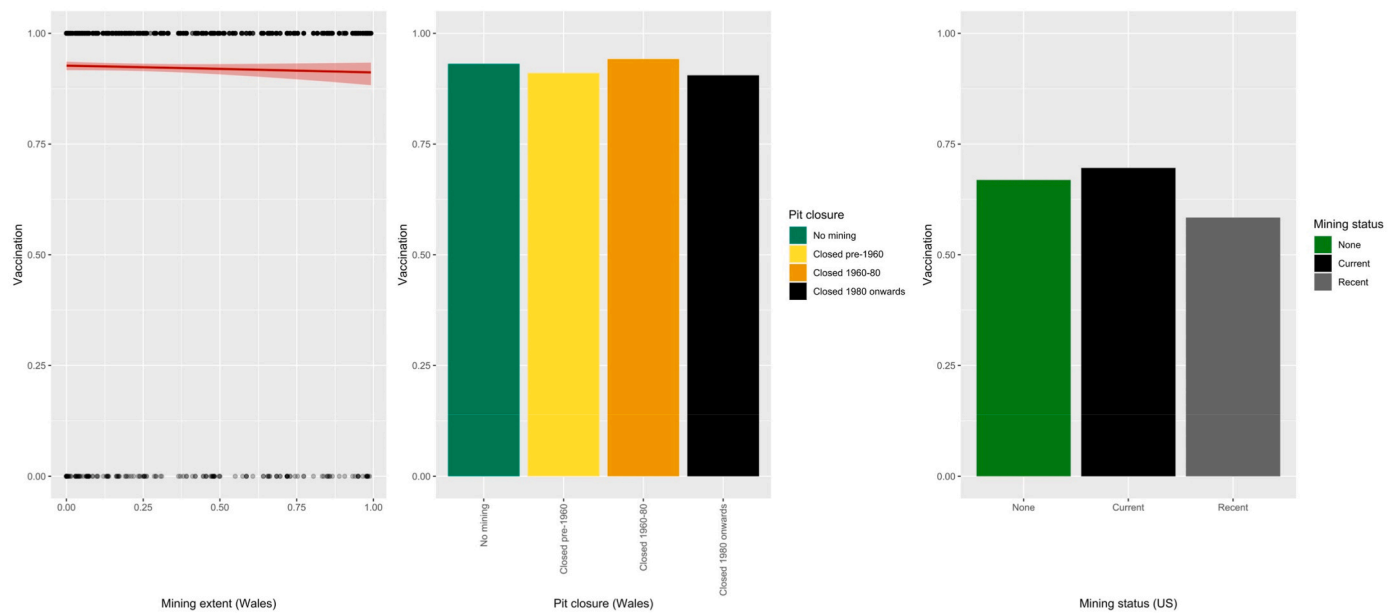


Fig. 4. Rates of vaccination (y-axes) as a function of mining extent (left panel), and pit closure (middle panel) in Wales; and mining status in the US (right panel).

behind the vaccine rollout. There was also a theme of having done ‘one’s own research’ rather than having passively accepted official narratives. Amongst unvaccinated respondents in Wales, one was suspicious of financial gain and interests behind vaccine rollout. A second believed things were being manipulated, a view which seemed to be preceded by a broader low regard for politicians who she believes lie to people. A third suggested that statistics are being hidden from public view:

“It’s really hard to get any realistic, reliable numbers and figures out of anybody, anywhere. When you go looking for some, numbers, and actually start looking into it and dissecting it and asking yourselves, well, actually, what does it mean? Well, who are those people? What does that mean? Who, who are these people? Overly hard because it’s like they’re trying to hide something. I don’t know, but because it’s hidden, you don’t know what.”

Another interviewee was similarly suspicious of a hidden agenda:

“It feels like the government is really really trying to push it and bully people into having it, I’m thinking no, well, why are they trying to bully people so much? I don’t understand it.”

Similar expressions of COVID scepticism were evident in Appalachia. One interviewee discussed being more afraid of the vaccine than of COVID and would cite examples of people dying from the vaccine. Another stated that she “just doesn’t trust the government, plain and simple.” Suspicion was expressed towards the promotion of the vaccine, especially any incentivization to get vaccinated. One interview describes how she was not against having the vaccine from the outset “I did consider it, I thought about getting it” but how “when I seen how hard they were pushing it ... I just didn’t want to do it.” They went on to describe politicians as “all a bunch of liars.”

These perspectives amongst unvaccinated interviewees were in stark contrast to the high levels of trust in public health organisations expressed by many vaccinated interviewees. Indeed, some vaccinated respondents expressed anger towards unvaccinated respondents for their lack of trust in the scientific consensus:

“Even before COVID, I was aware of an anti-VAX culture and the blinking term ‘I’ve done my research’ just absolutely fries my brain, you know? They’ve watched some other lunatic on YouTube spout rubbish, but then don’t have the education, perhaps, to be able to understand [....] clinical trials.”

9.1. Vaccine individualism

There was some consensus between unvaccinated and vaccinated respondents on the theme of vaccine individualism. Many vaccinated participants were uneasy with the idea of vaccination not being a matter of personal choice and expressed recognition of unvaccinated people’s autonomy, like this interviewee from Wales:

“I would try and persuade them, but it is their choice at the end of the day, isn’t it?”

That said, in most cases, vaccinated respondents expressed collectivist justifications for getting vaccinated and unvaccinated respondents stressed the importance of individual choice and responsibility. While some vaccinated respondents invoked an abstract or imagined sense of social solidarity, the interviews also indicated that these “altruistic” reasons were being made more directly on the basis of actual family relations. Hence, via the qualitative data, we can pick up how ideas of individualism and responsibility are viewed partly through a lens of familial and informal ties.

One unvaccinated interviewee in Wales expressed the theme of vaccine individualism especially clearly:

“I really don’t need a vaccine ... I’m vegetarian, I don’t smoke, I don’t drink, I don’t do drugs, I’m of a healthy weight, I exercise every day, I don’t have diabetes, any sort of chronic health condition. I see no need for it.”

“My health is my responsibility; other people’s health is theirs. I have no responsibility whatsoever towards others, the health of others. It’s for them to make their own decisions on risk and choices for their own lives.”

Another expressed a similar sentiment:

“While I’m while I’m given the choice, my, my preference and choice is to say no, thank you, I’ll take my, I’ll take my risk I’m not gonna get vaccinated just ‘cause someone else thinks I should, you know, as long as they don’t try and impose it on me, or, or, honestly, try and convince me. You know it’s live and let be. And if that if that means I die, well, so be it, I die, that was my choice.”

Conversely, many vaccinated respondents framed the decision to get vaccinated as being part of one’s responsibility to others. One from Wales explained his decision:

"I have strong ideas of society, rightly or wrongly, my view is quite utilitarian, for the greater good, I see the need for protecting most people and obviously that's why I had the vaccine."

Another later put it more pointedly:

"We do meet people who aren't vaccinated, I think 'Well, if, if everybody was like that, we'd all be six foot under now, quite frankly.'"

The contrast between individualist anti-vaccine or vaccine-hesitant views and social solidaristic, pro-vaccination views is of further significance given the coalfield context. As stated above, the survey results indicate vaccine individualism is higher in local areas which have/or have had greater coal mining activity. The qualitative evidence shows that sources of social solidarity for vaccine uptake can vary – for example, to protect their own multigenerational families to more abstract notions of 'society and 'the collective good.' But we also, in our qualitative data, find cases of primarily vaccinated respondents, in both countries, referring to their attachment to mining communities and active community involvement.

In the Welsh case, one vaccinated respondent describes a family history with coal mining in the South Wales valleys dating over 200 years. He describes that for those who have a family connection to the industry, there continues to be an identity and awareness, but also believes this to be in decline, being less prevalent amongst young people and people who recently moved to the area. He displays an acute awareness of the political history of coal mining closure and is actively involved his trade union. Another vaccinated interviewee referred to his uncle as a "very proud miner" who "always wants to tell you about '85" [the 1984-5 miner's strike]. A third vaccinated interviewee's grandfather worked down the mines and had a father who worked in the industry, although not as a miner. She discussed at length the repercussions of the strike for her family in the interview. This is not to say that unvaccinated Welsh participants did not have connections to coal mining, but they tended not to discuss them at length in the interviews. For example, one referred briefly to an ex-husband who worked in the industry during the 1984-5 strikes and to having a mortgage and a young child at the time.

In Appalachia, we also found examples of vaccinated participants with a strong sense of coal mining legacy and community consciousness. One talked at length about the impact of coal mining and being involved in the community. She expressed strong affection for "her community," has lived there all her life, and has family members who worked in coal mines. She described herself as 'a unionist' and related her local advocacy work and not being shy to speak out against, for example, anti-vax views in the community to an Appalachian way of doing things:

"I've tried to encourage in my community ... pushing the vaccine, I worked with our governor, I was in a commercial for our area stressing the importance of getting the vaccine. I've always been very outspoken, I think that's kind of an Appalachian thing too, like, we have a history of people speaking out you know, unionising in the coal mines and I think we've lost that, and I like to think of myself as bringing that back, but I am just really loud and they smoke a lot of cigarettes, so you know I don't know. The advocacy work is so hard."

This case highlights the challenges of promoting the vaccine locally and coming up against anti-vaccine views within the community. Another interviewee described coming from a coal mining family. Despite not having worked in coalmining himself, he described "a deep connection to the coalfield." He expressed a strong sense of place: "I'm definitely part of the community ... I work actively with the historical society in [town] near where I grew up". Whilst fully vaccinated, he says this has been despite widespread opposition from within the community, which he put down to a combination of "low education" and "Republican politics in the community."

These interviewees provide us with similar perspectives of community involvement and coalfield connection coupled with an awareness of widespread anti-vaccine sentiment locally. Other cases provide further

examples of vaccinated respondents acutely aware of the coal mining legacy and challenges now facing people in the community. For example, one stated: "I belong here. This is my county, this my county. Erm yes I care about our community [but] we are kind of divided."

9.2. Confused concern

The final factor was the least apparent of the four in the interviews, but we identified several examples of our interviewees struggling with the epistemic challenges of identifying reliable information about vaccination and the pandemic more broadly.

Several unvaccinated respondents had misgivings about both official advice and some sources of unofficial advice online:

"Well, it's all on the Internet, but where on the Internet? I'm not sure. You know, I'm not the sort of guy that reads something by Johnny Come Lately and then takes it for gospel. You know, I've got an education, I've got a brain of my own and I think about things. UmI've done all of that stuff, you know, and I've got my own personal life experience of um, you know the medical world and the medical profession."

Some interviewees who were sceptical of vaccines were keen to distinguish their scepticism from 'far-fetched' views held by others:

"People are going on about 5G and um a load of stuff that I think is quite far-fetched erm, so I don't really want to associate myself with that side of things ... I've heard of things: UK Column and uh, what's his name, Del Bigtree or something like that, I think they're the kind of more wackier end of the scale, whereas I trust a sort of more uh, not academic, but they're kind of more balanced articles by more professional sort of people."

A handful of interviewees faced dilemmas due to what they saw as contradictions between the general health information about vaccine benefits and risks and specific advice they had received concerning their own health predicaments. One from Wales, who was single dose vaccinated, described delaying vaccination due to being pregnant:

"I delayed it because of knowledge of things like thalidomide and things like that where, on one hand, you're told it's absolutely fine, and then it turns out there's side effects that people weren't aware of initially."

This interviewee was in favour of COVID restrictions adopted by the Welsh government, compared to the UK government, described lockdown as a positive experience personally, and distanced herself from anti-vax views amongst people she knows. But, at the same time, expressed concern and dismay over the way vaccine views have been polarized and how some non-vaccinated people are talked about.

Another had a health condition and received conflicting advice:

"I've heard it from both sides, I've heard it from a GP that is saying no, don't get it because you know your life is at risk here is the information, and I've heard it from a [hospital doctor's] point of view saying 'no you need to have it, this is the reasons why', so I've had it from both sides and I'm more saying no, but you know when you just feel pressured into it, I think I'm kind of more leaning into being pressured into getting the injections."

10. Summary

Overall, whilst there are similarities and continuities between vaccinated and unvaccinated participants around anxieties about vaccines and around the balancing of individual choices and collective responsibilities, they were more divided on the issue of COVID scepticism and could be distinguished from each other on political mistrust. There is also a clear tendency for vaccinated interviewees to stress solidarity and doing the right thing for others and unvaccinated to assert personal choice.

Interviewees who appeared especially embedded within their communities or who had strong connections to 'coal culture' were not

obviously more mistrustful of vaccination or politics more generally. One of the key findings to come out from the qualitative research, especially in the Appalachian context, were stories of people with deeply felt affinities to coal and the community retaining commitments to the solidaristic politics associated with industries and distancing themselves from antivaccine attitudes around them. For these people, the coal mining legacy may act as a continued source of solidarity, whereas for others, solidarity was invoked more in relation to their immediate families, to society, or to the public as a whole.

Vaccine individualism was connected to how people understood the quality of their own familial and social relations. This, in turn, seems to shape perceptions of the relative risk of spreading the disease to others. In addition, people's senses of vaccine confidence are shaped by "stories" of people they know in their daily lives (e.g., an uncle died from COVID-19 after getting vaccinated), as much as the information they receive through media and health bodies. This points to the distinction between the sorts of information which flow via linking and vertical forms of social capital and those which flow through informal social relations. Amongst unvaccinated participants, there is clear evidence that lack of trust in vaccines and public health information is intermingled with political mistrust and disaffection, with the latter having an important bearing on the former. A clear difference between the two areas was the greater awareness of division over COVID-19 in Appalachia than in Wales. Appalachian respondents would regularly understand their own communities as divided and split on the issue of vaccination.

11. Discussion

Survey respondents in post-industrial and deindustrialising coalfield regions of Wales and the US express more scepticism of COVID-19 vaccination and official narratives around the pandemic than those living in areas without a history of coal mining. This was reflected in lower vaccine uptake in formerly coalmining US counties and in areas of Wales where pits closed most recently.

It is difficult to disentangle the cultural residue of coal mining culture, in general, from the social and economic scarring resulting from its decline, but our results are probably more consistent with the latter. In the US, currently, mining counties have similar levels of vaccine confidence and uptake as non-mining counties. In Wales, areas with the most recent and adversarial experiences of mining's decline showed lower uptake.

In Wales, we observed slightly diverging results when using different measures of coalfield status. The extent of historical mining predicted attitudes but not vaccination, while the recency of local pit closure predicted both attitudes and odds of being vaccinated. That vaccine uptake was lower in areas where pits closed most recently might reflect the tumultuousness of the late 20th century for mining communities. During the 1980s, coal mining communities experienced one of the most infamous periods in British industrial relations history, including the year-long miner's strike, when Prime Minister Margaret Thatcher famously described striking miners as 'the enemy within.' Residual mistrust in the state is thus especially plausible in communities where mining continued into this period.

The rationale behind this project was that areas' industrial history will have shaped the health attitudes and behaviour of their residents. Our expectations were that the difficult experiences of deindustrialisation which coalfield Wales and Appalachia have undergone would have undermined trust in authorities, with negative consequences for vaccine uptake. However, it also seemed plausible that the norms of social solidarity which coal mining inculcated might have made a framing of vaccination as a pro-social act persuasive in these communities. In our survey data, we found that coalfield residents were indeed more vaccine hesitant than people from other areas. However, contrary to expectations, attitudes towards vaccination appeared more individualistic in coalfield areas (in the US, current but not former mining areas expressed

greater vaccine individualism) rather than less so.

The specific political environments of coalfields in the two countries were an appealing explanation for our results – the Welsh coalfields' confrontation with the Thatcher government of the 1980s and the political realignment of the Appalachian coalfields both seem like plausible drivers of greater vaccine hesitance. However, our post-hoc analyses found that adjusting for political allegiance did not change the association between coalfield status and our outcome measures. Thus, although the broader political values and experiences of coalfield residents still seem important in explaining our results, they cannot be straightforwardly explained by political partisanship.

It is striking that we observe such similar findings across the two settings when one considers the important differences between the two settings. Firstly, healthcare systems differ markedly in Wales, the cradle of the National Health System, and the US, with its decentralised private model. Residents of the two settings will have very different experiences of accessing healthcare and may have perceived the offer of a 'free' vaccination differently. Secondly, while the Appalachian coalfields have experienced their aforementioned political realignment, the Welsh coalfields have remained stubbornly loyal to the Labour Party (Scully, 2017). Despite these important differences, coalfield residents in the two settings share higher rates of vaccine hesitance.

The qualitative interviews presented an opportunity to explore whether participants also understood their vaccination decisions using this historical framing or whether any such influence was implicit. Our results present an interesting contrast with the quantitative data, whereby some vaccinated respondents used the collectivist heritage of their areas as a rhetorical frame to argue for the importance of vaccination as a prosocial act, while unvaccinated respondents often framed their vaccination decisions as rational individualist calculations of direct health consequences. Thus, an expectation which was not confirmed by the quantitative data appeared to be a framing which some vaccinated respondents used to make sense of their decisions, while our quantitative finding that living in a former coal mining area is a risk factor for vaccine hesitance appears to be driven by implicit mechanisms – 'common sense' about the wisdom of trust in institutions perhaps – rather than explicit references to historical injustices. Our use of mixed methods was important in arriving at this relatively nuanced position.

11.1. Limitations

One limitation of the study was that the exposure to coal mining history was not equivalent between the two countries. In Wales, the exposures were the proportion of each MSOA with mineworks underneath as a proxy for the likely extent of historical mining; or the period in which local pits closed. In the US, counties were classified as currently mining, formerly mining, or non-mining. Part of the reason for this was the availability of comparable data, but given that coal mining has largely ceased in Wales and is ongoing in Appalachia meant that reconciling the exposure between countries was not possible. Furthermore, the geographical units were not equivalent – MSOAs are generally finer-grained than counties. Thus, the comparison between countries was somewhat analogous rather than direct. That said, there were striking parallels between findings in the two countries suggesting that coalfields share structural vulnerabilities for vaccine hesitancy.

Another limitation is that causation is not easy to establish here. While there is no risk of reverse causation – attitudes and behaviours towards COVID-19 vaccination clearly did not cause the coal industry or its decline – it is difficult to establish whether the coal mining history of these areas really were causal to vaccination attitudes and beliefs. One might argue that our results simply reflect the broader social gradients in vaccination shown elsewhere in the literature. We used three main techniques to try to strengthen our argument. Firstly, adjusting for income and education does not reduce the association between mining status and the outcomes markedly, which seems inconsistent with an explanation of residual confounding by socioeconomic status, where one

would expect the attempted adjustment to reduce the association. Secondly, looking at coalfield communities in two countries provides an internal replication of our findings, consistent with the idea that there is a general connection between deindustrialising coalfield regions and vaccine hesitance which transcends a specific context.

Finally, our results are a snapshot of a particular timepoint in the pandemic and attitudes towards vaccination, COVID-19, and public health more broadly are multicausal and will respond dynamically to changing circumstances. Further work is needed to monitor the health attitudes and behaviours of coalfield residents as we move on from the pandemic.

11.2. Strengths

The study also had important strengths. The study, while building on a broader literature of looking at social gradients in COVID-19 outcomes and vaccination uptake (Bambra et al., 2020), is novel in focusing on coalfields. The quantitative results are based on large, professionally conducted surveys which, other than oversampling coalfield regions by design, are representative. Looking at two countries also, as we say above, provides evidence of a broader link between this class of community and vaccine hesitance. Similarly, our mixed methods design allows us to triangulate between two methodological approaches and develop a richer understanding of the phenomenon than either approach would alone.

11.3. Conclusions and implications

Deindustrialising coalfield regions represent a distinct class of the economically disadvantaged community common across Europe and North America. The present study suggests that these communities face specific challenges to public health which are currently under-recognised. While we focus on two specific coalfield areas, the ‘family resemblance’ we identify may well apply to other coalfields internationally, both those similarly in decline and those which may fall into decline as the world transitions away from fossil fuels. Attention is needed to address the unintended public health consequences of energy transition and economic change more generally by ensuring that coal communities are supported to transition into healthy and resilient post-coal communities.

CRedit authorship contribution statement

Christopher W.N. Saville: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Robin Mann:** Methodology, Formal analysis, Writing – review & editing, Supervision. **Anthony Scott Lockard:** Conceptualization, Writing – review & editing. **Aidan Bark-Connell:** Investigation, Formal analysis, Writing – review & editing. **Stella Gmekpebi Gabuljah:** Investigation, Formal analysis, Writing – review & editing. **April M. Young:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition. **Daniel Rhys Thomas:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition.

Data availability

A de-identified version of the survey data are available from the corresponding author. We are unable to share detailed geographical data for reasons of participant anonymity, but very happy to share data for secondary use.

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Appendix A. Supplementary data

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