The Psychological Gains from COVID-19 Vaccination: Should the mentally distressed be prioritized?*

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Abstract

We estimate the impact of COVID-19 vaccination on psychological well-being using information from a large-scale panel survey representative of the UK population. Exploiting exogenous variation in the timing of vaccinations, we find that vaccination increases psychological well-being (GHQ-12) by 0.12σ, compensating for around one-half of the overall decrease caused by the pandemic. This improvement is driven by individuals who became mentally distressed during pandemic, supporting the prioritization of this group in vaccination roll-outs. It persists for at least two months, and is associated with a decrease in the expected likelihood of contracting COVID-19 and higher engagement in social activities.

Keywords: Psychological well-being, COVID-19 vaccination.
JEL Classification: I18, I31

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1 Introduction

The COVID-19 pandemic has delivered a profound shock to our lives. Just in the UK more than 140,000 lives had been lost by October 2021 and there has been a strong deterioration of the psychological well-being of the population (Banks and Xu, 2020; Belot et al., 2020; Pierce et al., 2020; Proto and Quintana-Domeque, 2021; Proto and Zhang, 2021). Compared to pre-pandemic levels, by November 2020 the average psychological well-being, as measured by the 12-item General Health Questionnaire (GHQ-12), had declined by 27% standard deviations and the number of people exhibiting mental distress had increased by 7 percentage points, relative to a baseline of 20%.[1] The decline in mental well-being has been particularly acute among women and young adults (Adams-Prassl et al., 2020; Etheridge and Spantig, 2020; Giuntella et al., 2021; Stantcheva, 2021; COVID-19 Mental Disorders Collaborators, 2021).

Science reacted at an unprecedented speed and, by the end of 2020, several vaccines had been developed and cleared by regulators around the world. The first mass vaccination program started in December 2020 in the UK with two main population groups being prioritized: i) front-line health and social workers in order to protect health systems and ii) elderly and clinically vulnerable populations as they have the greatest mortality risk. Clinical trials have shown that vaccines decrease the probability of contracting and transmitting COVID-19, as well as the severity of infections (Abu-Raddad et al., 2021; Harder et al., 2021; Leshem and Lopman, 2021; Lipsitch and Kahn, 2021; Polack et al., 2020; Pritchard et al., 2021; Salo et al., 2021; Thompson et al., 2021). However, since in clinical trials participants are unaware of whether they are receiving the vaccine or a placebo, little is known about how vaccination may contribute to the recovery of mental health.

In this paper we estimate the short-term direct impact of vaccination on psychological well-being exploiting evidence from the UK vaccination roll-out, with a particular focus on individuals who became mentally distressed during the COVID-19 period. This group, which accounts for around 16% of the UK population, was not explicitly prioritized in the roll-out, despite the dramatic impact that the pandemic had on psychological well-being. We use data from the UK Household Longitudinal Study *Understanding Society*, a large-scale panel survey representative of the overall population that provides detailed information on the vaccination status of participants as well as their psychological well-being, assessed through the GHQ-12. Taking advantage of the panel structure of the data, we compare the evolution over time in the psychological well-being of individuals who were vaccinated a few weeks before the survey with individuals of the same age and priority group who had not been vaccinated yet. To limit endogeneity concerns, we use the timing

[1] Authors' calculations using information from the UK Household Longitudinal Study (Institute for Social and Economic Research, 2021).

of invitations for vaccination as an instrumental variable. We focus mainly on individuals aged 40 to 80 who are not health or social workers, as for this group we can exploit plausibly exogenous variation in the timing of invitations.

The first jab improves the GHQ-12 mean symptom score by 0.12 standard deviations (standard error=4%) and it decreases the number of mentally distressed individuals by 4.3 percentage points (standard error=2.1), measured within one month of vaccination.[2] The improvement in psychological well-being caused by vaccination compensates for around one-half of the overall decrease in well-being produced by the pandemic and is similar in size to the psychological gain associated to being employed. The impact is driven mainly by individuals who became mentally distressed during the pandemic. Vaccination increases their psychological well-being by 0.38σ (s.e.=0.11) and the probability of being mentally distressed decreases by 17 p.p. (s.e.=5). On the contrary, vaccination does not seem to improve the well-being of individuals with prior concerns about potential unknown side effects of vaccination, who account for around 8% of the population. The effect of vaccination is slightly larger for women and non-whites, but the difference is not statistically significant. The positive impact of vaccines lasts for at least two months, which is the maximum period that we can observe individuals in the survey following their vaccination. Unfortunately, we lack statistical power to estimate accurately the impact of the second jab, as only a few hundred people had received their second dose at the time of the last available survey wave. The point estimate is close to zero, but the estimation is too imprecise to discard that the effect was similar to the first jab (p.e.=2% σ, s.e.=8%).

Individuals benefit from vaccination through at least two channels. First, vaccinated individuals experience a large decrease in the expected probability of contracting COVID-19 during the following month (p.e.=-0.17σ, s.e.=0.06). Second, vaccination improves social life and increases the enjoyment of daily activities. Vaccinated individuals are less likely to report that they feel lonely (p.e.=-8% σ, s.e.=4%), they are more likely to go for a walk (p.e.=15% σ, s.e.=6%) and they are more likely to report that they enjoy normal day-to-day activities (p.e.=0.15σ, s.e.=0.06). We do not observe any significant impact on self-reported general health or on the probability of contracting COVID-19, which is consistent with vaccination requiring several weeks to be effective in preventing infections, while our analysis focuses on individuals who were vaccinated few weeks before the survey. Similarly, there is no significant effect on economic outcomes.

The consistency of our analysis relies on the assumption that the differential timing of invitations is driven by exogenous differences in the speed of the roll-out across different geographic areas, and it is not correlated with time-variant unobserved factors affecting individuals' psychological well-being. A number of robustness tests support this hypothesis. An event study analysis shows that the psychological well-being of individuals

[2]In what follows, for simplicity, we abbreviate 'standard deviation' as 'σ', 'point estimate' as 'p.e.', 'standard error as 's.e.', and 'percentage point' as 'p.p.'.

who were vaccinated at the time of the survey had evolved in the past similarly to non-vaccinated ones of similar age and priority group. Furthermore, we show that the timing of vaccinations is not correlated with local COVID-19 incidence. Results are also unchanged when we allow for time-variant shocks at the regional level, and to a number of alternative sampling restrictions and weighting strategies.

Our estimates are qualitatively similar but less precise when we exploit the regression discontinuity design observed in the March 2021 survey around the 49 year old threshold. Just above this threshold around 90% of individuals are vaccinated at the time of the survey, compared to only 45% just below. The well-being of individuals above this age threshold is 0.13σ higher (s.e.=0.07) and the probability of being mentally distressed is 10 p.p. lower (s.e.=4), a significant gap that is not observed in previous waves. The gap is twice as large when we restrict the analysis to individuals who were mentally distressed prior to vaccination.

We contribute to a growing literature analyzing how the pandemic has affected psychological well-being and to the literature on the impact of vaccination. Our paper is closest to recent work by Perez-Arce et al. (2021), who estimate the impact of the first dose of the COVID-19 vaccine on mental distress using data from Understanding America Study. Using a fixed-effects model, they find a 0.04σ increase in the mean score of the four-item Patient Health Questionnaire. This magnitude is remarkably similar to our estimates using a fixed effect model (p.e.=0.05σ). However, it is substantially lower than our preferred specification (p.e.=0.12σ), where we allow for the existence of time-variant age-specific shocks and we use an instrumental variable strategy to account for the potential endogeneity of vaccination.[3] Moreover, our data allows exploring the different mechanisms through which vaccination can affect psychological well-being. Finally, our paper speaks to the discussion on the optimal design of vaccination roll-outs and the selection of priority groups (Buckner et al., 2021; Mazereel et al., 2021; Smith et al., 2021; Stip et al., 2021; Yang et al., 2021). An important novelty of our work is the focus on individuals who became mentally distressed during the pandemic. We show that this group strongly benefits from vaccination, suggesting that they should be prioritized in vaccination roll-outs.

[3] As Perez-Arce et al. (2021), page 9, acknowledge, "it is possible that the difference in trajectories across the vaccinated and not vaccinated groups arose not due to a causal effect of receiving the vaccine dose but from sorting at the time of the vaccine roll-out, such that individuals with an increased likelihood of becoming less depressed were also more likely to decide to get vaccinated." We tackle this problem using an instrumental variable strategy and a regression discontinuity design that exploit the exogenous timing of invitations.

2 Institutional Context

In early December 2020, the UK became the first country to approve a COVID-19 vaccine for emergency use and to start a mass vaccination program. The vaccination roll-out was implemented by the National Health Service (NHS). The NHS sent invitations to registered patients according to the priority ordering and individuals receiving an invitation could schedule an appointment for vaccination, which was implemented mainly by local GPsc(JCVI, 2021; UK Department of Health and Social Care, 2021). The system did not allow individuals to get vaccinated without an invitation letter. Older individuals were contacted first, with earlier invitations also for residents and staff of care homes, front-line health and social care workers, clinically extremely vulnerable, and at-risk groups with underlying health conditions (see Figure A1). The roll-out did not explicitly target individuals with low psychological well-being, except for some extreme cases.[4]. Both AstraZeneca and Pfizer/BioNTech were administered with patients not being able to choose or being told about which vaccine they would receive before attending their appointment.

As shown in Figure A2, a new wave of the pandemic took place shortly after the beginning of the vaccination process leading to the introduction of the third national lockdown on 6 January 2021. The lockdown rules were uniform across different areas of the country. The population was requested to stay at home and they were not allowed to meet indoors with people from other households. Following the decline in the infection rate, on February 22 a roadmap for lifting the lockdown was published (Cabinet Office, 2021). The first phase started on March 8, and it included the return to face-to-face education in schools and the relaxation of social contact restrictions. The 'stay at home rule' was removed on March 29.

3 Data

We use data from the UK Household Longitudinal Study *Understanding Society*, a large-scale longitudinal survey representative of the UK population (Benzeval et al., 2021). We focus on the eight COVID survey waves, between April 2020 and March 2021. The survey was conducted mainly online, with a telephone follow-up of web non-respondents who reside in households where no one regularly uses internet for some waves. The survey population includes around 20k individuals, of which 42% participated in all eight waves, 52% participated in all but one wave, and 58% in all but two waves.

Table A1 provides information on the main summary statistics for the adult population in the survey (columns 1-4) and for the main sample used in our analysis, which includes individuals between 40 and 80

[4]Individuals with extreme psychiatric conditions were considered clinically vulnerable and included as a priority group 6, following the vaccination of all individuals aged 65 and over (JCVI, 2021; Smith et al., 2021)

years old, excluding health and social workers (columns 5-6). Around 53% are women, the average age is 51, 90% self-identify as white, 90% were born in the UK, 75% live in an urban place, 29% are college graduates, 63% live with a partner and 22% are parents of a child who is less than 15 years of age.[5] More detailed information about the definition of the main variables is available in Table A2.

Vaccination Two survey waves took place during the vaccination process. Wave 7 was launched on 27 January 2021, when the vaccination roll-out was reaching individuals aged around 60 to 80 years old, and lockdown rules were strictest. Wave 8 was launched on 24 March 2021, during the first phase of the lockdown easing and when individuals from 40 to 60 years old were being vaccinated.

According to the survey, by the end of January 2021 around 24% of UK adults had received an invitation for vaccination, of which 18% had already received the 1st jab and 4% had made an appointment for vaccination. By the end of March 2021, when the following survey wave took place, the share of individuals who had received an invitation had increased to 71%, of which 65% were vaccinated and 3% had an appointment. Around 5% of individuals had already received also their second jab.

Priority groups The survey allows to identify groups prioritized in the roll-out. Following the categorization of the NHS, it classifies respondents into (i) individuals with no risk of serious illness if they contract COVID-19 (61% of the population), (ii) clinically vulnerable (36%) and (iii) clinically extremely vulnerable (5%).[6] Furthermore, approximately 10% of the population had received a letter, text or email from the NHS indicating that they are at risk of severe illness if they catch coronavirus, and were advised to stay at home ('shielded'). The roll-out also prioritized health and social workers, who account for 12% of the population, and individuals who care for someone who is sick, disabled or elderly (9%).

Psychological well-being: general health questionnaire Psychological well-being is measured using the General Health Questionnaire (GHQ-12). It includes 12 questions and is commonly used as a screening tool to detect current state mental disturbances and disorders in primary care setting (Goldberg and Hillier, 1979). The specific questions are available in Appendix A. Each question has four possible answers: "not at all", "no more than usual", "rather more than usual" and "much more than usual". We rely on two measures derived from the GHQ-12 index that have been broadly used in the literature (Pierce et al., 2020; Banks and Xu, 2020; Proto and Quintana-Domeque, 2021; Etheridge and Spantig, 2020). First, we use the *mean symptom score*, which is constructed summing up the 12 GHQ items, coded from 0 to 3, resulting in a scale

[5] All descriptive statistics and analysis are performed using the weights, stratification and clustering defined by *Understanding Society*.

[6] More detailed information is available in the User Guide for *Understanding Society* COVID-19, page 33 (University of Essex, Institute for Social and Economic Research, 2021).

from 0 (the least distressed) to 36 (the most distressed). To ease interpretation we standardize this measure and invert it, so that higher values indicate higher psychological well-being. Second, we rely on a *caseness indicator* that captures more acute cases of mental distress (Morris et al., 2017). This indicator takes value one for individuals who have replied “rather more than usual” and “much more than usual” to at least four of the twelve questions of the GHQ-12.

As shown in Figure A2, during the first months of the pandemic, mental health measures deteriorated dramatically. In April 2020 the average psychological well-being was 0.21σ lower than in 2019. As cases fell during the summer, mental health improved, but with the arrival of the second wave in Fall 2020, the average psychological well-being dipped even further. By November 2020 it had declined by 0.27σ compared to pre-pandemic levels. Similarly, in Fall 2020 about 26% of the respondents reported clinically significant levels of mental distress, as measured by the caseness indicator, compared to just under 20% in the years leading up to the pandemic.

Psychological well-being exhibits a strong age-gradient. The mean symptom score is around 0.25σ higher among individuals above 60 years old than for individuals between 40 and 60. Psychological well-being is also correlated with physical health, but the relationship is relatively weak. Among individuals who are extremely clinically vulnerable, 35% of them are also mentally distressed, compared to 27% in the rest of the population.

Probability of contracting COVID-19 In each survey wave about 5% of respondents report having experienced symptoms since the previous wave that could have been be caused by coronavirus, and 2% report that they have tested positive in a COVID-19 test.

Survey respondents also report their expected likelihood of contracting COVID-19 in the near future. In November 2020, prior to the vaccination roll-out, around 9% of respondents declare that it is likely or very likely that they will get infected during the following month (see Figure A3 (a)). This self-reported risk of contracting COVID-19 predicts mildly the actual probability of contracting COVID-19. Among individuals who report that the probability is very high, 4.3% report a positive test result during the following two months, compared to 1.8% of individuals who had reported a very low risk (see Figure A3 (b)).

The perceived risk decreases monotonically with age. For instance, around 11% of individuals aged between 40 and 60 consider that it is likely or very likely that they will contract COVID-19 during the following month, compared to only 4% of individuals above 60 years old.

Attitude towards vaccines Before the roll-out, around 18% of individuals report that they are unlikely or very unlikely to vaccinate (see Figure A4). The share of people unwilling to vaccinate decreased over time as the roll-out was implemented, down to 5% in March 2021. Survey respondents declare their main motivations for getting the jab as to avoid catching COVID-19, to recover social life and to protect other people (see Figure A5). The main concern is the possible existence of unknown side-effects (11% of respondents).

Social life and enjoyment of daily activities We use three proxies for the intensity of social interactions. First, individuals are asked how often they felt lonely in the previous 4 weeks. In November 2020, around 44% of people report feeling lonely some of the time or often, compared to 40% in 2019 before the pandemic. Self-reported loneliness tends to decrease with age. About 56% of individuals below 40 report feeling lonely sometimes, compared to 36% of middle-age individuals and 30% of individuals above 60. Second, in some survey waves, respondents report how many days they walk weekly. The average individual in the sample walks five days a week for at least 10 minutes. Third, as part of the GHQ-12 questionnaire, individuals are asked whether they enjoy day-to-day activities. Around 55% reply than they do so less than usual, compared to only 5% who enjoy them more.

3.1 Labor market and household finances

Around 60% of individuals are employed, they work on average 28 hours a week and 36% work from home always or often. Household weekly income is close to GBP 650 (USD 900). Approximately 2/3 or respondents report that they are living comfortably or doing alright, and most of them (78%) do not expect their financial situation to change in the following three months. During the past 4 weeks they have saved on average around GBP 250 (USD 350). To measure the marginal propensity to consume, respondents are asked how receiving a (hypothetical) one time payment of GBP 500 (USD 670) would affect their spending, borrowing and saving behaviour over the following three months. Around 19% of them declare that they would spend more.[7]

Additional data sources We also collected daily information on COVID-19 incidence during the period of our analysis at the level of Middle Layer Super Output Areas (MSOAs), as measured by the daily number of COVID-19 positive tests per 100,000 inhabitants. The average MSOA includes around 4,000 households.

Finally, we use administrative data from Public Health England on the percentage of people by age who received the 1st COVID-19 vaccination over time. As shown in Figure A6, once the roll-out reached a cohort, it took just a few weeks to complete its vaccination.

[7] We combine the responses to a question where the origin of the payment if not specified and a question where the fictitious payment was done by the government (variables 'mpc1' and 'mpc1b').

4 Empirical Analysis

4.1 Factors predicting invitation for vaccination

The timing of invitations is consistent with the official guidance of the NHS. We observe a strong age gradient (see Figure 1). In the January 2021 survey, 99% of individuals aged 80 or older had already received an invitation, compared to only 20% of younger adults. Similarly, at the time of the March 2021 survey, invitations had been sent to 99% of individuals above 50, and to only 40% of younger individuals. Moreover, as shown in Appendix B, members of priority groups are more likely to have been invited for vaccination at the time of the survey.

The data also confirms that individuals with high levels of mental distress were not prioritized, and we do not observe any correlation between the speed of the roll-out and the prior local incidence of COVID-19.

4.2 Short-term impact of vaccination

In this section we investigate the impact of vaccination on psychological well-being during the first weeks after vaccination. First, we use a difference-in-differences (DID) empirical strategy. We compare individuals vaccinated in the weeks leading up to the survey with individuals of the same age and priority group who had not been vaccinated yet. Second, to address potential endogeneity concerns and reverse causality, we combine the DID estimation with an instrumental variables (IV) approach, where we use as an instrument for vaccination whether individuals have received an invitation. Third, we study a number of mechanisms that may underlie the observed relationship between vaccination and psychological well-being. Fourth, we focus on individuals who became mentally distressed during the pandemic. Fifth, we verify the robustness of our estimates to alternative specifications, different sample restrictions, and we test for the existence of non-random participation into the survey. Sixth, we consider several extensions and heterogeneity analyses. Finally, we estimate the short-term impact of vaccination using a regression discontinuity design, exploiting a sharp discontinuity around age 49 in the vaccination rate of individuals surveyed in March 2021.

4.2.1 Difference-in-differences

We estimate the short-term impact of vaccination using a stacked DID model with two treatment groups: (i) individuals aged 61-80 who were vaccinated at the time of the January 2021 survey wave and (ii) individuals aged 40-60 who were vaccinated in the March 2021 survey wave.[8] The control groups include other individuals of the same age and priority group who were not vaccinated by the time of the corresponding survey. Individuals in the treatment group were vaccinated mostly during the four weeks prior to the survey, while individuals in the control group were mostly vaccinated in the following weeks (see Figure A7). For both age groups, we consider one survey wave after the potential treatment and six survey waves before, i.e. we consider individuals aged 61-80 from April 2020 until January 2021 (waves 1-7 of the survey) and individuals aged 40-60 from May 2020 until March 2021 (waves 2-8 of the survey). More precisely, we estimate the following equation:

$$\begin{aligned} y_{it} = & \sum_{j \in \text{sample}} \alpha_j \cdot I(j=i) + \sum_{e=-6}^{1} \sum_{a=40}^{80} \beta_{e,a} \cdot I(e=t) \cdot I(a=age_i) + \\ & + \sum_{e=-6}^{1} \sum_{p} \sum_{g} \lambda_{e,p,g} \cdot I(e=t) \cdot I(p=prioritygroup_{it}) \cdot I(g=agegroup_{it}) + \gamma \cdot \text{Vaccinated}_{it} + \epsilon_{it} \end{aligned} \tag{1}$$

where we have denoted event time $t = 1$ for the survey wave when a given age group could have been first vaccinated (i.e. for individuals aged 61-80, $t = 1$ refers to January 2021 and, for individuals aged 40-60, $t = 1$ in March 2021). The outcome variable y_{it} is the standardized GHQ-12 score for individual i at time t, and $Vaccinated_{it}$ is a dummy variable that takes value one if individual i was vaccinated or had arranged an appointment for vaccination at time t.[9] We consider three set of controls. We capture unobserved time-invariant heterogeneity including a set of individual fixed effects (first term on the right-hand side). In some specifications we also include a set of event time fixed effects interacted with age dummies (second term), which allows to control for the potential existence of time-variant age-specific shocks. This is likely to be a relevant concern in this context, as we observe that the psychological well-being of different age groups had evolved differently during the pandemic, perhaps reflecting the differential impact of higher infection rates and lock-downs on the well-being of individuals in different age groups (see Figure A8).[10] Finally, we also

[8] A recent literature has pointed out that in DID setups with staggered adoption the interpretation of standard two-way fixed effects estimates as the average treatment effects for the treated sub-populations may not be adequate in the presence of heterogeneity and dynamic effects (e.g. see Callaway and Sant'Anna (2020)). The use of a stacked DID helps to address these concerns by ensuring that (i) we are comparing 'switchers' only to 'not yet treated' individuals and (ii) both groups are receiving the appropriate weight.

[9] Around 3% of the population had an appointment for vaccination at the time of the survey but was not vaccinated yet. As shown in the robustness section, this choice does not affect results.

[10] For instance, when the situation improved in the summer of 2020, individuals above 60 experienced a significant increase in their psychological well-being, compared to younger individuals,

include in some specifications a set of event time fixed effects interacted with age group (40-60 or 61-80) and priority group (third term), allowing for the existence of time-variant shocks that may affect differently different priority groups.[11] In all estimations, we use survey weights and we cluster standard errors by survey strata.

Our sample includes all participants in the survey with two exceptions. We exclude health and social workers as they were strongly prioritized and mostly vaccinated by the end of January 2021. We also drop from the analysis 158 individuals aged 40-60 (2% of the sample) who had been invited for vaccination at the time of the January 2021 survey, as they were targeted as members of some special priority group. The remaining sample includes around 48k observations corresponding to 8k different respondents. As shown in section C, these sample restrictions do not affect our results.

In Table 1, we report the results from estimating equation (1) using an OLS regression and different sets of controls. In column (1) we only include as controls survey wave fixed effects. The psychological well-being of vaccinated individuals is 0.21σ higher (s.e.=0.04) compared to non-vaccinated individuals in the same survey wave. Naturally, this estimate is likely to reflect a combination of selection biases and causal effects. In column (2) we also include individual fixed effects. The estimate becomes smaller, p.e.=0.047σ (s.e.=0.024), indicating that vaccinated individuals are positively selected in terms of their underlying psychological well-being, probably reflecting that they tend to be older and psychological well-being is increasing with age. In column (3) we allow for time-variant age-specific shocks, which leads to a substantial increase in the magnitude of the estimate: p.e.=0.14σ (s.e.=0.04). A possible explanation for this change in the magnitude of the estimate is that on average individuals above 60 experienced between November 2020 and January 2021 a deterioration of their psychological well-being relative to other age groups, perhaps due to their larger sensitivity to lockdown measures and to increases in the infection rate. This age group was more likely to be vaccinated during this period, and not accounting for this age-specific negative shock may lead to a downwards bias. Finally, in column (4) we report the estimate with the full set of controls included in equation (1), allowing also for different priority groups being exposed to different time-variant shocks. This additional set of controls leaves the estimate unchanged: p.e.=13% (s.e.=3%).

[11] In particular, we consider the following priority groups: keyworkers, 'shielded', clinically vulnerable, extremely clinically vulnerable, and carers.

Event study analysis The validity of the DID estimates relies on the assumption that, in the absence of vaccination, the psychological well-being of vaccinated and non-vaccinated individuals would have evolved similarly. This assumption would be satisfied if the vaccination timing for individuals in the same age and priority group was exogenous. To explore the plausibility of this hypothesis we conduct an event study analysis and we estimate the following equation:

$$\begin{aligned} \mathrm{y}_{it} = & \sum_{j \in \text{sample}} \alpha_j \cdot I(j=i) + \sum_{e=-6}^{1} \sum_{a=41}^{80} \beta_{w,a} \cdot I(e=t) \cdot I(a=age_i) + \\ & + \sum_{\substack{e=-6 \\ e \neq 0}}^{1} \gamma_k \cdot I(e=t) \cdot treatmentgroup_i + \epsilon_{ite} \end{aligned} \tag{2}$$

where y_{it} is the psychological well-being of individual i at event time t. We control for individual fixed effects (first term on the right-hand side), event time fixed effects interacted with age (second term), and a full set of event time dummmies interacted with the treatment group identifier (third term). The variable $treatmentgroup_i$ takes value one for individuals aged 61-80 who were vaccinated at the time of the January 2021 survey and individuals aged 40-60 who were vaccinated at the time of the March 2021 survey. We omit the event time dummy at t = 0, implying that the event time coefficients measure the impact relative to the survey wave just before vaccination.

As shown in Figure 2, both groups followed parallel trends in the past, supporting the assumption that they would have also followed parallel trends in the absence of the treatment. Moreover, consistent with our previous results, the event study also shows that psychological well-being increases significantly following vaccination.

4.2.2 Instrumental variables

While the results of the event study analysis support the validity of the DID empirical strategy, there might be at least two potential threats. First, there might be a problem of reverse causality. Individuals who are feeling depressed may be less likely to get vaccinated. Furthermore, there might be an omitted variable bias if there are unobserved (time-variant) factors that affect simultaneously the probability of being vaccinated and psychological well-being. To address these concerns, we combine the DID analysis with an instrumental variables strategy. We estimate equation (1) using the timing of invitations as an instrumental variable for vaccination. As shown in column (5) of Table 1, the IV estimate is slightly less precise but the point estimate is practically identical (p.e.=0.12σ, s.e.=0.04). In columns (6) and (7) we analyse separately the impact of vaccination for individuals aged 61-80 (waves 1-7) and 40-60 (waves 1-8). The impact of vaccination is similar for both groups.

The exogeneity of the instrument requires that the group of individuals who have not been invited yet for vaccination provide a good counterfactual for the evolution of well-being among individuals who have been invited for vaccination. To test this assumption, we conduct an event study analysis and we estimate equation (2) including in the treatment group individuals that were invited for vaccination and in the control group all other individuals of the same age. As shown in Figure 3, results confirm that invited and non-invited individuals had evolved similarly in the past, supporting the exogeneity of the instrument.

In addition to the exogeneity assumption, for the consistency of the IV estimator the exclusion restriction requires that invitations for vaccination only affect psychological well-being through their impact on vaccination. This assumption would not be satisfied if invitations somehow affect the well-being of individuals who decline to get vaccinated, a possibility we consider unlikely. Furthermore, the validity of the IV strategy also relies on the monotonicity condition, which in this context requires that, for all groups of individuals, receiving an invitation does not decrease the probability of being vaccinated. We do not observe in the data any individuals getting vaccinated without an invitation, indicating that this assumption is also satisfied.

So far we have used as outcome variable the GHQ-12 mean score. In Table A3 we reproduce the previous analysis using as an outcome variable an indicator for being mentally distressed. According to the IV specification, vaccination decreases the probability of being mentally distressed by 4.3 p.p. (s.e.=2.1 p.p.)

4.2.3 Mechanisms

We explore the possible mechanisms that may explain the positive impact of vaccination on psychological well-being.

Physical health and COVID-19 We rule out that the observed effect reflects an improvement in physical health (see Table A4). There is no significant effect on the probability of having had symptoms of COVID-19 during the month prior to the survey, testing positive, or on self-reported general health. This is consistent with evidence from clinical trials indicating that COVID vaccines are ineffective during the first weeks after vaccination (Polack et al., 2020). If anything, some subjects might have experienced negative side effects around 1 to 2 days after vaccination which might potentially affect negatively their mood, biasing downwards our estimates (Menni et al., 2021; Kuhlman et al., 2018).

While we observe no improvement in actual health at the time of the survey, vaccination decreases individuals' expected probability of contracting COVID-19 during the following month by 0.17σ (s.e.=0.06), indicating that they were convinced of the effectiveness of vaccines.

Social life Another mechanisms that seems to mediate the impact of vaccination on psychological well-being is the improvement of social interactions. Following vaccination, we observe a decrease in self-reported loneliness of 0.08σ (s.e.=0.04) and an increase in daily walking of 0.15σ (s.e.=0.06). Vaccination also leads to a higher enjoyment of daily activities (0.15σ, s.e.=0.06).

Labor market and household finances As shown in Table A5, we do not observe any significant effect on labor market outcomes, saving behavior or consumption. There are at least two possible explanations for this lack of impact. Individuals were vaccinated just a few weeks before the survey, limiting the scope for job market effects. Moreover, during the period that we study, work opportunities were limited by a lockdown that required working from home for a large share of the population.

4.2.4 Impact on individuals who became mentally distressed during the pandemic

Our analysis has shown that vaccination has a large and significant positive impact on psychological well-being. Next, we focus on the subset of individuals who became mentally distressed during COVID-19. We estimate equation (1) allowing for an interaction between vaccination and an indicator variable that takes value one for individuals who reported being mentally distressed September 2020 but not in January 2020, using invitations as an instrument for vaccination. We restrict this analysis to the last three waves of the survey (November 2020, January 2021 and March 2021), to ensure that our right-hand side variable is predetermined relative to the outcome variables.

We report these results in Table A6. As shown in column (1), the positive impact of vaccination is 1.5 times larger for this group (30% vs. 12%). The impact is also significantly stronger when we consider as the outcome variable a dummy for being mentally distressed at time t. Individuals who became mentally distressed between January and September 2020 and were vaccinated are 15 p.p. (s.e.=5) less likely to remain in this state after vaccination (column 2).

In columns (3)-(4) we consider the impact of vaccination on individuals who were already distressed before COVID-19. In this case, the impact of vaccination is similar to the overall population.

In columns (5)-(8), we investigate why vaccination has a larger impact on individuals who got distressed during COVID-19. Individuals with high levels of initial of mental distress seem to recover more strongly their social interactions. They experience a larger decrease in self-reported loneliness and a larger increase in their enjoyment of daily activities.

To investigate further how the impact of vaccination varies with the prior level of mental distress, we consider also a more granular measure of mental health, the *caseness score*. This score is derived by scoring the “rather more than usual” and “much more than usual” responses as 1, and summing them up, resulting in a range 0-12. As shown in Figure 4, the impact is largest for individuals with a caseness score above 8 (p.e.=0.38σ, s.e.=0.12).

Finally, we examine separately the impact for individuals who had were already distressed before COVID-19 and individuals who got distressed during the pandemic. As shown in Table X, the increase in psychological well-being is driven by the latter group.

4.2.5 Robustness and extensions

As shown in Appendix C, our results are robust to the inclusion as an additional control of the local COVID-19 incidence rate, allowing for time-variant shocks at the regional level, changes in the sample composition, and alternative survey weights. Furthermore, we do not observe any evidence suggesting that vaccination affected participation in the survey.

In Appendix D we also consider a number of extensions. First, we examine the impact of vaccination across the different dimensions of the GHQ-12 index. Second, we show that the impact does not vary significantly across different socio-economic groups. Third, we focus on individuals who were concerned with potential side-effects of vaccines. We show that they do not obtain any psychological benefits from vaccination. Fourth, we find that individuals experience an improvement of their psychological well-being already when they make the appointment. Finally, we explore the impact of the second jab, but results are imprecise and inconclusive.

4.2.6 Regression discontinuity design

We also estimate the impact of vaccination exploiting the regression discontinuity design (RDD) observed in the March 2021 survey. In this survey wave there exists a clear discontinuity in the age profile of people who are vaccinated (see Figure 5.a).[12] Just above age 49, around 90% of individuals are vaccinated compared to only 45% just below. The existence of this discontinuity is likely to reflect that age 50 was the cut-off for the end of the first phase of the vaccination roll-out. We exploit this fuzzy RDD to estimate how vaccination affects psychological well-being. A potential advantage of using this RDD is that it relies on weaker assumptions than the DID-IV. Its consistency requires that there are no other relevant discontinuities at the 49 year old threshold, an assumption which in principle seems plausible and it is partially testable. On the flip side, a drawback of RDD is its more limited statistical power, as it exploits information only for individuals around the threshold.

We estimate the following equations using information from the March 2021 survey wave:[13]

[12] Instead, in the January 2021 survey, vaccination rates increase linearly between age 65 and 75, without any visible discontinuity.

[13] We exclude from the estimation individuals who are exactly 49, as their vaccination rate (66%) is just in between the level

$$Vaccinated_i = \beta_{firststage} \cdot I(age_i > 49) + f(age_i) + \epsilon_i \tag{5.a}$$

$$y_i = \beta_{reducedform} \cdot I(age_i > 49) + g(age_i) + \eta_i \tag{5.b}$$

$$y_i = \beta_{fuzzy} \cdot \widehat{\text{Vaccinated}}_i + h(age_i) + \rho_i \tag{5.c}$$

where $Vaccinated_i$ is a dummy variable capturing the vaccination status of individual i in the March 2021 survey; $I(age_i > 49)$ is an indicator that takes value one if individual i was more than 49 years old; y_i is a measure of psychological well-being; $\widehat{Vaccinated}_i$ is the predicted value estimated in equation (5.a); and $f(age_i)$, $g(age_i)$ and $h(age_i)$ are flexible continuous functions that capture the relationship between the corresponding outcome variable and the *running variable* age. To increase precision, we also include as a control the lagged value of the outcome variable. We implement this regressions using the bandwidth selection procedure proposed by Calonico et al. (2014), local polynomials of order one at each side of the threshold, and a triangular kernel. The optimal bandwidth is around 10 years.

The first stage estimation (equation 5.a) shows that being above the 49 years of age threshold increases the probability of being vaccinated at the time of the March survey by 45 p.p. and, the estimation of the reduced form (equation 5.b), that individuals above this threshold have 0.13σ (s.e.=0.07) higher psychological well-being (Table A7, columns 1-2). According to the fuzzy RDD (equation 5.c), vaccination increases psychological well-being by around 0.30σ (s.e.=0.17). The estimate of the impact of vaccination on the probability of being mentally distressed is more precise. Individuals just above 49 years old are 10 p.p. (st.err.=4) less likely to be mentally distressed, implying that vaccination decreases the probability of being distressed by about 20 p.p. (s.e.=8) (columns 5 and 6). A placebo analysis shows that the gap in psychological well-being observed at the 49 years threshold did not exist in previous waves (column 7). Furthermore, as expected, the age density function does not exhibit any discontinuity at the 49 years threshold (Figure A9).

In the lower panel of Table A7 we conduct the same analysis restricting the sample to individuals who reported being mentally distressed during the previous six months. Consistent with our previous results, we find that the impact of vaccination is stronger in this sample. Just above the 49 year threshold psychological well-being is 0.32σ (s.e.=0.15) higher and the probability of being distressed is 19 p.p. (s.e.=8) lower. These results are also supported by the RD plots, where we can observe a clear gap at the threshold for the first stage, and for the share of distressed individuals (Figure 5).

The fuzzy RDD estimates tend to be twice as large as the DID-IV estimates, but they are imprecise

of individuals aged 50-60 (around 94%) and individuals aged 40-48 (around 45%). We also exclude Health and Social workers, a group which was prioritized and had been vaccinated earlier.

and the difference is not statistically significant. An additional possible explanation for this difference is that each approach identifies the impact on a different segment of the population. In the DID-IV approach the estimate is obtained by comparing individuals of the same age and priority group who were invited or not for vaccination, while in the fuzzy RDD approach we are comparing individuals just above and below the threshold. The identity of 'compliers' is also differs. The DID-IV identifies the impact for individuals who would get vaccinated if they receive an invitation. Instead, the fuzzy RDD provides information on the impact of the treatment for individuals around 49 whose vaccination status would change depending on their age.

4.3 Persistence of the effect

The above evidence shows that vaccination has a large immediate effect on psychological well-being. Next we examine whether this effect persists at least during the period during which we can track respondents, between January and March 2021. More precisely, we compare the well-being of individuals vaccinated in January vs. the well-being of individuals of similar age who were vaccinated in February and March. If the effect of vaccines fades away over time, we would expect to observe a higher level of psychological well-being among individuals who have been vaccinated more recently.

We consider in our analysis all waves that took place in 2020 (before vaccination started) and the March 2021 wave (i.e. we exclude from this analysis the January 2020 wave), and we focus on the group of people who are more than 60 years old and less than 80, as for this group we can observe some variation in the timing of vaccination. Around one third of them had received their first jab in January 2021, and the rest got vaccinated during February and March. As shown in Table A8, the psychological well-being at the end of March 2021 of individuals who were vaccinated in January is slightly higher than the well-being of individuals who were vaccinated in February and March, although the difference is not statistically significant (p.e.=0.05σ, s.e.=0.04). This pattern suggests that the gains in psychological well-being do not fade away during the first two months, otherwise we would have observed a higher psychological well-being among individuals who have been vaccinated more recently.

5 Discussion

Using evidence from the UK vaccination roll-out, our analysis highlights that the benefits of vaccination are not limited to their impact on physical health. Vaccines have a large positive impact on psychological well-being, compensating for around one-half of the decrease in psychological well-being caused by the pandemic. The effect is particularly large for mentally distressed individuals, who account for around one fourth of the adult population.

Our results strongly suggest that it might be advisable to prioritize the mentally distressed in vaccination roll-outs. An obvious advantage is that it would improve the overall psychological well-being of the population. Moreover, mentally distressed people tend to have significantly higher utilisation rates of the health system. For instance, according to our data they are 50% more likely to use outpatient and inpatient services.[14] Improving their psychological well-being might help to ease the pressure on health systems.

There are several potential limitations of our study. First, we estimate only the direct impact of vaccinations on individuals who received the vaccination. Our estimate does not capture important indirect channels such as the positive externality provided by other individuals' vaccination. Second, our analysis identifies the short-term of vaccination. In the longer term vaccinations might have additional knock-on effects, contributing to the relaxation of the lock-downs that constraint labor market activity and social interactions. More research is also needed to determine whether the positive effects caused by the first jab also apply to the second jab and to boosters.

[14] Using information from wave 6 of the survey, we observe that 31% of mentally distressed individuals use hospital and clinic outpatient services and 12% in-patient services, compared to only 21% and 8% respectively for the rest of population.

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Tables

Table 1: Impact of vaccination on psychological well-being

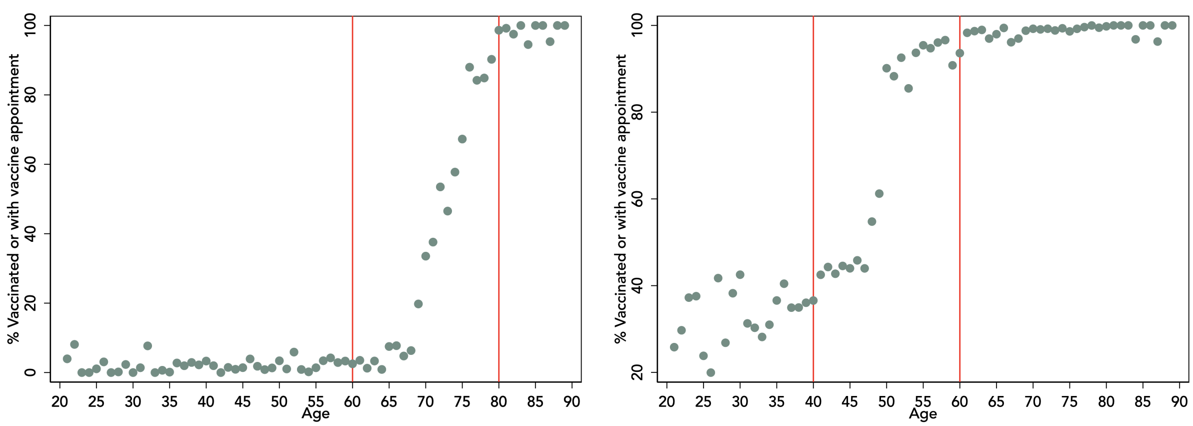
	(1) OLS	(2) DID	(3) DID	(4) DID	(5) IV-DID	(6) IV-DID	(7) IV-DID	(8) DID
1st vaccination	0.214***	0.047**	0.140***	0.128***	0.118***	0.121***	0.119*	0.108***
	(0.042)	(0.024)	(0.037)	(0.033)	(0.037)	(0.036)	(0.066)	(0.032)
2nd vaccination								0.019
								(0.085)
First stage F					5479	4314	1965	
N	48,016	47,710	47,710	47,376	47,348	27,510	19,866	28,494
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave*Age FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Wave*Priority FE	No	No	No	Yes	Yes	Yes	Yes	Yes
Sample	40-80	40-80	40-80	40-80	40-80	61-80	40-60	61-80

Notes: The outcome variable is the standardized inverted GHQ-12 Likert score. All regressions include survey wave fixed effects. Columns 2-8 include individual fixed effects, columns 3-8 include a set of time event dummies interacted with age, and columns 4-8 a set of priority group dummies interacted with time event dummies and age groups. In columns 5-7 vaccination is instrumented using invitations for vaccination. In column 6 we consider only the 61-80 age group and in column 7 the 40-60 age group. Column 8 considers both the 1st and 2nd vaccination for the 61-80 age group. All regressions use sample weights and standard errors are clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figures

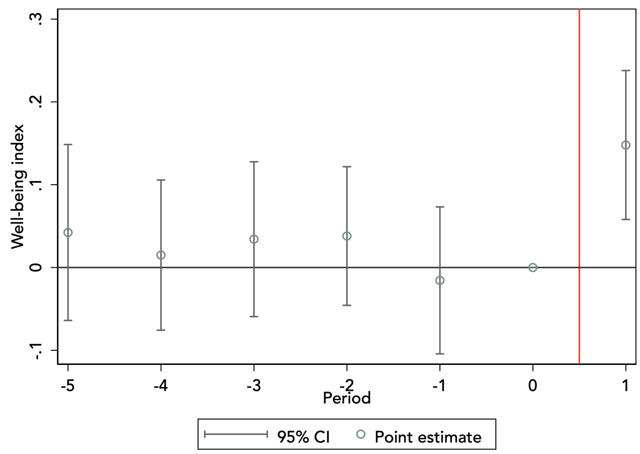
Figure 1: Vaccination rate by age.

(a) 27 January 2021 (survey wave 7) (b) 24 March 2021 (survey wave 8)



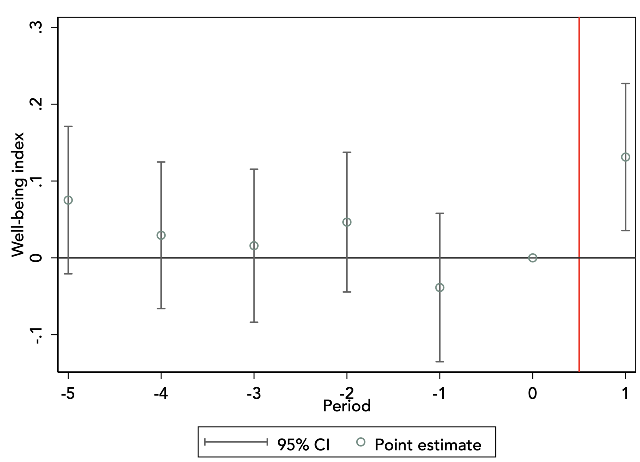
Notes: Percentage of individuals who were vaccinated or had an appointment for vaccination by age group in wave 7 (panel a) and wave 8 (panel b). Source: Authors' elaboration using data from *Understanding Society*.

Figure 2: Event study - Impact of vaccination on psychological well-being



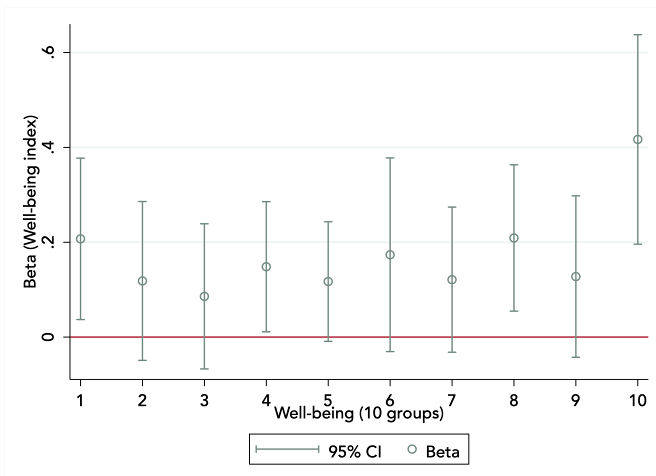
Notes: The figure reports the estimates from the event study analysis of the DID using equation (2). The outcome variable is the standardized and inverted GHQ-12 mean score. The treatment group includes individuals aged 61-80 who were vaccinated at the time of the January 2021 survey and individuals aged 40-60 who were vaccinated in March 2021 survey. For individuals age 61-80 (40-60), we denote the November 2020 (January 2021) survey wave as the baseline period, and index all waves relative to that one.

Figure 3: Event study - Impact of invitation for vaccination on psychological well-being



Notes: The figure reports the estimates from the event study analysis of the IV-DID using equation (2). The outcome variable is the standardized and inverted GHQ-12 mean score. The treatment group includes individuals aged 61-80 who had been invited for vaccination by the time of the January 2021 survey and individuals aged 40-60 who had been invited before the March 2021 survey. For individuals age 61-80 (40-60), we denote the November 2020 (January 2021) survey wave as the baseline period, and index all waves relative to that one.

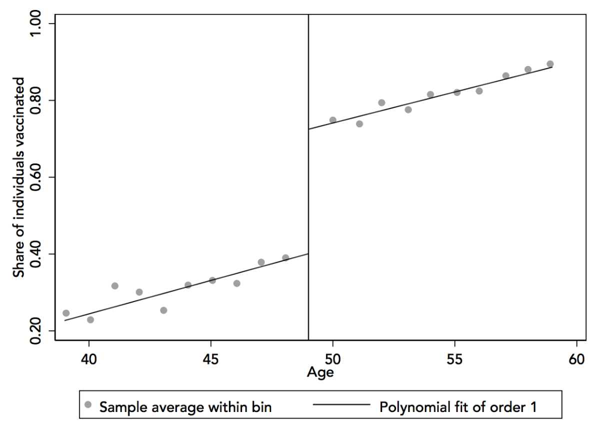
Figure 4: Impact of vaccination on psychological well-being, by the variation in psychological well-being during the pandemic.



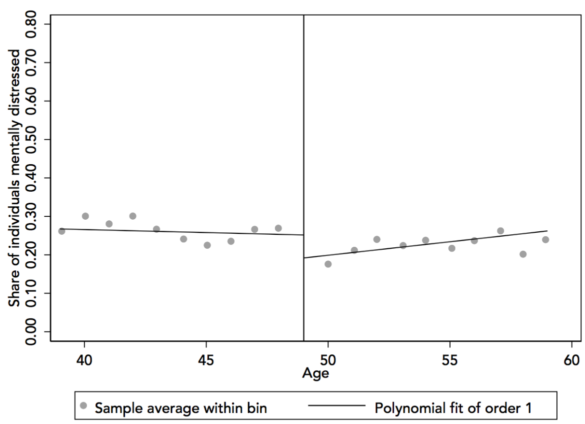
Notes: Coefficient plot of the impact of vaccination on the standardized and inverted GHQ-12 mean score in March 2021, by the well-being index measured in September 2020, grouped in 10 ascending categories, according to the pandemic impact vs. the pre-pandemic baseline well-being: higher scores are associated with larger difference vs. the baseline. We consider ten possible categories: 1 (from -36 to -5, 12.06%), 2 (from -4 to -3, 7.85%,), 3 (-2, 6.59%), 4 (-1, 9.44 %), 5 (0, 15.59%), 6 (1, 11.04%), 7 (2, 8.97%), 8 (3, 6.68%), 9 (from 4 to 6, 11.42%), 10 (from 7 to 36, 10.36%)

Figure 5: Regression discontinuity plots

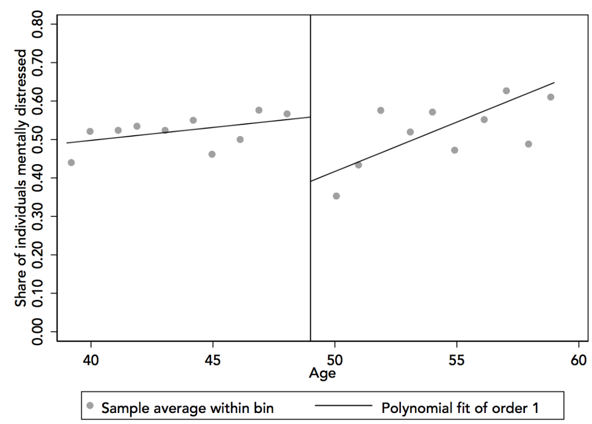
(a) Vaccination rate by age, March 2021.



(b) Mental distress by age, March 2021, full sample.



(c) Mental distress by age, March 2021, sample of individuals mentally distressed in previous 6 months.



Notes: In sub-figures (a) and (b) the sample includes all individuals aged 39-59 who participated in the 2021 March survey of *Understanding Society*. Sub-figure (c) includes information from individuals who reported being mentally distressed in September 2020, November 2020 or January 2021. All three plots omit individuals aged 49 and in health and social Care occupations.

Appendices

A Appendix: GHQ index

The GHQ index is constructed as the sum of the following 12 different questions, each one scaled from 0 to 3 (0, not at all; 1, no more than usual; 2, rather more than usual; 3, much more than usual).

- **a. concentration**: Have you recently been able to concentrate on whatever you're doing?
- **b. lack of sleep**: Have you recently lost much sleep over worry?
- **c. playing a useful role**: Have you recently felt that you were playing a useful part in things?
- **d. capable of making decisions**: Have you recently felt capable of making decisions about things?
- **e. constantly under strain**: Have you recently felt constantly under strain?
- **f. problem overcoming difficulties**: Have you recently felt you couldn't overcome your difficulties?
- **g. enjoy day-to-day activities**: Have you recently been able to enjoy your normal day-to-day activities?
- **h. ability to face problems**: Have you recently been able to face up to problems?
- **i. unhappy or depressed**: Have you recently been feeling unhappy or depressed?
- **j. losing confidence**: Have you recently been losing confidence in yourself?
- **k. believe worthless**: Have you recently been thinking of yourself as a worthless person?
- **l. general happiness**: Have you recently been feeling reasonably happy, all things considered?

B Factors predicting invitations and vaccinations

To investigate the role played by other individual characteristics, we estimate the following equation:

$$y_{it} = \sum_{a=41}^{80} \alpha_a \cdot I(a = age_i) + \beta \cdot I(t = March_{2021}) + X_{it} \cdot \gamma + \epsilon_{it} \quad (3)$$

where y_{it} is an indicator variable that takes value one if individual i had been invited for vaccination at the time of survey wave t. As explanatory variables we consider a full set of age dummies, a survey wave indicator and a vector of individual characteristics which includes information on prior mental and physical health, industry, occupation and keyworker status, and the (standardized) local COVID-19 incidence rate measured at the beginning of the roll-out. We use survey weights in our estimation and we cluster standard errors by survey strata. We restrict the analysis to individuals aged 61-80 in the January 2021 survey wave and 40-60 in the March survey wave, as only these age groups experience some relevant (within age) variation in vaccination status during this period. Our results are essentially unchanged if we consider instead the overall sample.

The estimates are reported in Table A9, column (1). As expected, members of priority groups more likely to have been invited for vaccination. The main effect is observed for health and social care keyworkers (24 p.p). We also observe significant effects for other priority groups: carers (11 p.p.), clinically extremely vulnerable individuals (6 p.p.) and vulnerable individuals (5 p.p.), and individuals who were shielding (10 p.p.). On the other hand, the survey confirms that individuals with high levels of mental distress were not prioritized (p.e.=-0.009, s.e.=0.015).

Most importantly for our empirical strategy, we do not observe any correlation between the speed of the roll-out and the local incidence of COVID-19 at the beginning of the roll-out. The estimate is a rather precise zero (p.e.=-0.003, s.e.=0.006), indicating that in areas where COVID-19 incidence is one standard deviation higher the probability of receiving an invitation may be up to 1.5 p.p. higher or 0.9 p.p. lower.

Vaccination The immense majority of people who had received an invitation, around 95%, got vaccinated or was was waiting for an appointment. To study which factors affected the decision of getting vaccinated, we estimate equation (3) for the sample of individuals who received an invitation, taking as outcome variable taking a dummy that takes value one if the individuals have made an appointment or received their first vaccine dose, and zero if individuals received an invitation but failed to make an appointment.

As shown in Table A9, columns (2), vaccination rates are significantly higher among priority groups and among individuals living with a partner. Individuals' concerned with the potential existence of vaccination side effects are 8 p.p. less likely to vaccinate. We observe also some differences by geographic area, but we do not observe any significant correlation between vaccination rates and COVID-19 incidence. Similarly, we do not observe that previous mental distress in any way predicts vaccination.

C Robustness

We examine the robustness of our main results to the inclusion of additional controls, the sample composition, alternative survey weights, and we explore the possibility of non-random attrition.

Additional controls In column (1) of Table A10, we estimate our preferred specification, i.e. equation (1) using invitations as an instrument for vaccination, and we add employment as an additional control. As expected, including employment as a control does not affect the estimated effect of vaccination. Moreover, the magnitude of the two estimates is quite similar. Being employed is associated to a 0.13σ (s.e.=0.05) increase in psychological well-being compared to the 0.12σ (s.e.=0.04) improvement caused by vaccination. In column (2), we allow for time-variant shocks affecting the 12 geographical regions of the UK by including in the specification a set of 'age group*survey wave*region' fixed effects. The estimate is essentially the same (p.e.=0.12σ, s.e.=0.04), suggesting that regions where the roll-out was relatively faster were not exposed to unobserved time-variant shocks affecting psychological well-being.

An additional potential threat to the validity of the analysis would be that the variation in the speed of the roll-out across different geographical areas is driven by underlying differences in incidence rates, which may affect psychological well-being. However, results are also unchanged when we control for the local incidence of COVID-19 at the time of survey (column 3), which is negatively correlated with psychological well-being but, as discussed above, is uncorrelated with vaccination rates.

Sample restrictions Our baseline sample includes individuals aged 40-80. In column 4 we restrict the sample to individuals aged 45-55 and 65-75, to minimize the possibility that the variation in invitation status that we exploit is driven by some unobserved factor which affects also psychological well-being. This sample restriction does not affect significantly our estimates (p.e.=0.13σ, s.e.=0.05). Estimates are smaller, but significantly different from zero when we extend the analysis to all individuals in the survey, independently of their age (see column 5, p.e.=0.08σ, s.e.=0.03), when we only consider individuals who participated in all waves of the COVID survey (column 6, p.e.=0.07σ, s.e.=0.04) and when we give the same weight to all observations (column 7, p.e.=0.07σ, s.e.=0.02).

Non-random attrition A potential threat to the validity of the analysis is that vaccination may have affected participation in the survey. For instance, an upward bias would arise if individuals affected by vaccination side-effects were less likely to participate in the survey. To investigate this issue, we examine whether the probability of participation in the surveys conducted in January and March 2021 (waves 7 and 8) was lower for age groups with higher vaccination rates during the week leading up to the survey. We use administrative data from Public Health England, which provides information on vaccination rates by age group aggregated in fifteen 5-year intervals. To test for the existence of non-random attrition, we estimate the following equation using data from all survey waves:

$$y_{at} = \sum_{j \in \text{set of age groups}} \alpha_j \cdot I(j = a) + \sum_{w=2}^{8} \beta_w \cdot I(w = wave_{at}) + \gamma \cdot VaccinationRate_{at} + \epsilon_{at} \tag{4}$$

where the outcome variable y_{at} is the share of individuals in a given age group who participated in the survey conducted at t. The specification includes a set of age group fixed effects (1st term on the right-hand side) and survey wave fixed effects (2nd term). The main variable of interest, $VaccinationRate_{at}$, is the share of individuals in a given age group who were vaccinated during the week before the survey. We cluster standard errors at the level of age groups and, given the relatively low number of groups, we use bootstrapping.

If vaccination affects individuals' participation in the survey, we would expect this effect to be captured by coefficient γ. However, as shown in Table A11, we do not observe any significant relationship between the share of individuals in a given age group who were vaccinated just before the survey wave and survey participation (p.e.=0.23, s.e.=0.14).

D Extensions

In this section we provide a number of additional analyses. First, we examine the impact of vaccination across the different dimensions of the GHQ-12 index. Second, we study whether the impact is heterogeneous across different socio-economic groups. Third, we investigate whether there is any anticipation effect when individuals receive the invitation or make an appointment. Finally, we explore the impact of the second jab, using the information from a few hundred people who had received it by the time of the March 2021 survey.

Dimensions of the GHQ-12 index The GHQ-12 index aggregates information from 12 different questions. In Table A12, we estimate the impact of vaccination separately for each question of the index. To ease the interpretation, similarly to what we did for the average GHQ-12 score, we standardize and invert each variable. The largest impact of vaccination is observed on the ability to concentrate, the enjoyment of day-to-day activities, feeling of general happiness, lower likelihood of feeling unhappy or depressed, and of losing confidence in oneself. All these effects are statistically significant and the point estimate is above 0.10 σ.

Heterogeneity We examine the impact of vaccination separately for different groups of individuals according to gender, ethnicity, education, employment, family structure and number of friends. The effect of vaccination is slightly larger for women, and for individuals who are more educated, employed, not living with a partner and not working from home, but none of these differences is statistically significant at standard levels (see Figure A10).

Attitude towards vaccines The fear of future unknown side-effects might mediate the impact of vaccines on psychological well-being. We estimate our IV-DID model allowing for an interaction between vaccination and a dummy variable that takes value zero for individuals who had expressed concerns with side-effects in the November 2020 survey and value one otherwise. In column (1) of Table A13 we report the results of the first stage estimation. Most individuals concerned with side-effects get vaccinated when they receive an invitation (p.e.=75 p.p., s.e.=7 p.p.), though their take-up rate is significantly lower than the rest of the population (p.e.=17 p.p., s.e.=7 p.p.). In column (2) we report estimates for the reduced form analysis (i.e. we regress psychological well-being on invitations). Invitations have no significant impact on the psychological well-being of individuals concerned with side-effects (p.e.=-0.09σ, s.e.=0.10), in contrast with the significantly larger impact experienced by other people (p.e.=0.22σ, s.e.=0.11). In column (3) we estimate the 2-stage least square model, instrumenting vaccination decisions with invitations. As expected, the point estimate is negative and slightly larger than the reduced-form (p.e.=-0.13σ, s.e.=0.14). Overall, our results suggest that vaccine hesitancy undermines the psychological benefits of the vaccination roll-out.

Timing of the effect The survey information allows to identify four different phases of the vaccination process: (i) individuals who have not received an invitation yet for their first jab, (ii) individuals who have received an invitation but have not made an appointment, (iii) individuals who have the made the appointment but are not yet vaccinated, and (iv) individuals who have already received their first jab.

We explore the impact of each of these events -invitation, appointment and vaccination- using equation (1). As shown in Table A14, column 1, we do not observe any increase in the psychological well-being for individuals who received the invitation but did not make the appointment. However, we do observe a large increase in well-being for individuals who have received the invitation and made an appointment but are not yet vaccinated (p.e.=0.15σ, s.e.=0.07) and for individuals who have already received their first jab (p.e.=0.15σ, s.e.=0.07). The existence of a large positive effect already at the time of the appointment is consistent with an anticipation effect of the future consequences of vaccination.

Second vaccine So far we have focused on the impact of receiving the first jab. We investigate the impact of the second jab using the information provided by a few hundred individuals who had received the 2nd jab at the time of the March 2020 survey. Among individuals older than 60, practically all of them (around 98%) had received their first jab and 6% had already received also their second jab. As shown in column 7 of Table 1, the impact of the second jab is not significantly different from zero (p.e.= 0.02σ, s.e.=0.08), but the estimate is quite imprecise and we cannot reject that the effect was similar to the impact of the same jab.

E Appendix: Additional Tables

Table A1: Summary statistics

	Population Above 16				Main sample	
	N	Mean	Min	Max	N	Mean
Individual characteristics						
Female	103819	0.53	0	1	48097	0.49
Age	106227	50.84	16	101	48479	60.64
White	106266	0.90	0	1	48479	0.95
Born in UK	106266	0.90	0	1	48479	0.92
Urban	105188	0.75	0	1	48479	0.73
College	106266	0.29	0	1	48479	0.27
Living with partner	106266	0.63	0	1	48479	0.72
Parent 0-15 children	75231	0.22	0	1	36729	0.18
Priority groups						
Health or social worker	106266	0.12	0	1	48479	0.00
Shielded	106266	0.10	0	1	48479	0.12
Cares for sick-disabled-elderly	102064	0.09	0	1	47824	0.09
Receiving formal care	36229	0.02	0	1	16473	0.02
Clinically vulnerable	106266	0.36	0	1	48479	0.43
Clinically extremely vulnerable	106266	0.05	0	1	48479	0.07
Health and social life						
Psychological well-being GHQ-12	106266	12.64	0	36	48479	12.06
Mental distress	106266	0.26	0	1	48479	0.22
Had COVID-19 symptoms	106220	0.05	0	1	48459	0.04
Tested COVID-19 positive	106266	0.01	0	1	48479	0.01
General health	35674	2.64	1	5	16192	2.69
Loneliness	106226	1.49	1	3	48457	1.40
Walking	35421	5.04	0	7	15651	5.16
Vaccine attitudes						
Unlikely to contract COVID19	87391	0.25	0	1	43607	0.28
Unlikely to get vaccinated	87430	0.17	0	1	43650	0.13
Not concerned with side effects	106266	0.92	0	1	48479	0.93
Labour market						
Employed	106193	0.60	0	1	48449	0.48
Weekly household income	68938	657.95	0	8000	34828	636.78
Hours worked	61089	27.62	0	100	21163	27.40
Works from home always or often	61556	0.36	0	1	21274	0.38
Financial security						
Financial situation (current)	68468	2.04	1	5	28419	1.99
Savings amount	34857	248.66	0	20000	15545	233.42
Financial situation (future)	68356	2.02	1	3	28376	2.04
Marginal propensity to consume	36782	1.87	1	3	16390	1.86
COVID-19 local incidence						
New cases per 100,000	104565	55.92	0	2533	47817	59.07

Notes: Columns 1-4 provide information for all survey respondents in waves 1-8 of the *Understanding Society* COVID-19 survey. Columns 5-6 provides information for the main sample used in the paper, which includes individuals between 40 and 80 years old, and excludes health and social workers. The means are population-weighted. The information for priority groups is defined in wave 6 (November 2020).

Table A2: Variable definitions

Variable name	Survey question	Scale
cvinvite - Invited for covid-19 vaccine	Have you been invited to have the coronavirus vaccination by the NHS (even if you have not had the vaccination yet)?	1. Yes 2. No
hadcvvac - Had covid-19 vaccine	Have you had a coronavirus vaccination?	1. Yes, first vaccination only 2. Yes, both vaccinations 3. No, but I have an appointment 4. No
aidhh - Cares for handicapped or other in household	Is there anyone living with you who is sick, disabled or elderly whom you look after or give special help to (for example, a sick, disabled or elderly relative, husband, wife or friend etc)?	1. Yes 2. No
nhsshield - NHS shielded patient	Have you received a letter, text or email from the NHS or Chief Medical Officer saying that you have been identified as someone at risk of severe illness if you catch coronavirus, because you have an underlying disease or health condition?	1. Yes 2. No
scsf1 - General health	In general, would you say your health is...	1. Excellent 2. Very good 3. Good 4. Fair 5. Poor
hadsymp - Has had symptoms that could be coronavirus	Have you experienced symptoms that could be caused by coronavirus (COVID-19)	1. Yes 2. No
sclonely_cv - Loneliness	In the last 4 weeks, how often did you feel lonely?	1. Hardly ever or never 2. Some of the time 3. Often
wday - 7 days walking	During the last 7 days, on how many days did you walk for at least 10 minutes at a time?	Numeric textbox: Days per week
wah - Working at home	During the last four weeks how often did you work at home?	1. Always 2. Often 3. Sometimes 4. Never
finnow - Subjective financial situation - current	How well would you say you yourself are managing financially these days? Would you say you are...	1. Living comfortably 2. Doing alright 3. Just about getting by 4. Finding it quite difficult
finfut_cv3 - Subjective financial situation - future	Looking ahead, how do you think you will be financially 3 months from now, will you be...	1. Better off 2. Worse off than you are now 3. Or about the same?
saved_cv - Savings amount	About how much have you personally managed to save in the last 4 weeks?	Numeric textbox: Pounds
mpc1 - Marginal propensity to consume	Now consider a hypothetical situation where you unexpectedly receive a one-time payment of GBP500 today. We would like to know whether this extra income would cause you to change your spending, borrowing and saving behaviour in any way over the next 3 months.	Over the next 3 months, I would: spend more than/the same as/less than than if I hadn't received the GBP500
riskcv19 - Risk of getting covid19	In your view, how likely is it that you will contract COVID-19 in the next month?	1. Very likely 2. Likely 3. Unlikely 4. Very unlikely
vaxxer2 - Likelihood of taking up a coronavirus vaccination	When you are offered the coronavirus vaccination, how likely or unlikely would you be to take it?	1. Very likely 2. Likely 3. Unlikely 4. Very unlikely

Table A3: Impact of vaccination on mental distress

	(1) OLS	(2) DID	(3) DID	(4) DID	(5) IV-DID	(6) IV-DID	(7) IV-DID	(8) DID
1st vaccination	-0.056***	-0.012	-0.039**	-0.036*	-0.043**	-0.035	-0.051	-0.016
	(0.017)	(0.014)	(0.019)	(0.019)	(0.021)	(0.027)	(0.033)	(0.025)
2nd vaccination								0.040
								(0.077)
First stage F					5479	4314	1965	
N	48,016	47,710	47,710	47,376	47,348	27,510	19,866	28,494
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave*Age FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Wave*Priority FE	No	No	No	Yes	Yes	Yes	Yes	Yes
Sample	40-80	40-80	40-80	40-80	40-80	61-80	40-60	61-80

Notes: The outcome variable is an indicator for having clinically significant levels of mental distress. All regressions include survey wave fixed effects. Columns 2-8 include individual fixed effects, columns 3-8 include a set of time event dummies interacted with age, and columns 4-8 a set of priority group dummies interacted with time event dummies and age groups. In columns 5-7 vaccination is instrumented using invitations for vaccination. In column 6 we consider only the 61-80 age group and in column 7 the 40-60 age group. Column 8 considers both the 1st and 2nd vaccination for the 61-80 age group. All regressions use sample weights and standard errors are clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Mechanisms - COVID-19, health, and social life

Outcome:	(1) Had symptoms	(2) Tested positive	(3) General health	(4) Risk perception	(5) Loneliness	(6) Weekly walking	(7) Daily activities
1st vaccination	0.003	0.008	0.069*	-0.169***	-0.081**	0.149**	0.152***
	(0.011)	(0.008)	(0.037)	(0.059)	(0.038)	(0.063)	(0.058)
N	47,363	47,376	15,202	43,029	47,365	13,848	47,376

Notes: In all columns we report estimates of equation (1), instrumenting the 1st vaccination with invitations, using sample weights and with standard errors clustered at the level of strata. All regressions include individual fixed effects, age times time event fixed effects, and fixed effects for priority groups interacted with time event and age group dummies. The outcome variables are: indicator for having had COVID-19 symptoms in column 1, having tested positive for COVID-19 in column 2, (standardized) self-assessed health in column 3 (based on question: "In general, would you say your health is...: excellent/very good/good/fair/poor"), (standardized) risk perception in column 4 (based on question: "In your view, how likely is it that you will contract COVID-19 in the next month? Very likely/Likely/Unlikely/Very unlikely"), (standardized) loneliness in column 5 (based on question: "how often one feels lonely: hardly ever or never/some of the time/often", and number of walking days in column 6 (based on question: "During the last 7 days, on how many days did you walk for at least 10 minutes at a time?"). In column 7 the outcome variable is an standardized measure of the answers to the question on the enjoyment of daily activities in the GHQ-12. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Labor market and household finances

Outcomes:	(1) Employed	(2) Hours worked	(3) Weekly income	(4) Home working	(5) Financial situation (current)	(6) Savings amount	(7) Financial situation (future)	(8) Marginal propensity to consume
1st vaccination	0.006	-2.434*	-0.231	-0.007	0.098*	-0.041	-0.057	0.066
	(0.010)	(1.424)	(0.186)	(0.021)	(0.056)	(0.091)	(0.109)	(0.097)
N	19,859	15,581	15,302	15,653	27,337	14,280	27,311	15,555

Notes: In all columns we report estimates of equation (1), instrumenting the 1st vaccination with invitation, using sample weights and with standard errors clustered at the level of strata. All regressions include individual fixed effects, age times time event fixed effects, and fixed effects for priority groups interacted with time event and age group dummies. The outcome variables are: an indicator for being employed in column 1, hours worked weekly in column 2, log weekly income in column 3 and an indicator for working from home in column 4, subjective financial situation now in column 5: "How well would you say you yourself are managing financially these days? Would you say you are...", amount saved in column 6, subjective financial situation in the future in column 7, and marginal propensity to consume in column 8. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: Impact on individuals with clinically significant levels of mental distress

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Outcome:	Well-being	Well-being	Distress	Distress	Perceived risk	Loneliness	Daily act
_Ivaccinate_1	0.120*	0.119*	-0.035	-0.034	-0.279***	-0.103**	0.10
	(0.062)	(0.061)	(0.028)	(0.028)	(0.057)	(0.042)	(0.06
_IvacXdistr_1	0.272***	0.260**	-0.139***	-0.124**	-0.044	-0.131**	0.205
	(0.085)	(0.117)	(0.048)	(0.055)	(0.065)	(0.064)	(0.10
1st vaccination * distressed always		0.013		-0.016			
		(0.083)		(0.034)			
N	14,238	14,238	14,238	14,238	14,146	14,232	14,23

Notes: The table reports the results of estimating the IV equation using data for survey waves between November 2020 and March 2021. The dummy variable *distressed in Sept.* value one for the sample of individuals who were mentally distressed in September 2020. All regressions include using sampling weights, individual fixed effects, age times time event fi and fixed effects for priority groups interacted with time event and age group dummies. The outcome variable is the standardized inverted GHQ-12 Likert score in columns 1-2, an in being mentally distressed in column 3, the (standardized) risk perception in column 4 (based on question: "In your view, how likely is it that you will contract COVID-19 in the next mo likely/Likely/Unlikely/Very unlikely"), (standardized) loneliness in column 5 (based on question: "how often one feels lonely: hardly ever or never/some of the time/often" and enjoying dail in column 6, which is one of the GHQ-12 dimensions. Standard errors are clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Regression discontinuity design

	(1) First stage	(2) RDD	(3) Fuzzy RDD	(4) Placebo	(5) RDD	(6) Fuzzy RDD	(7) Placebo
Survey Wave:	March 2021	March 2021	March 2021	Waves 1-7	March 2021	March 2021	Waves 1-7
Outcome:	1st vaccination	Well-being	Well-being	Well-being	Distress	Distress	Distress
Panel A: All							
Age>49	0.445***	0.132*	0.296*	-0.017	-0.101***	-0.198**	0.014
	(0.034)	(0.073)	(0.166)	(0.024)	(0.037)	(0.077)	(0.011)
Bandwidth	9.7	8.6	8.9	10.2	8.5	10.0	11.6
N	10,388	8,864	8,864	60,098	8,864	8,864	60,098
Panel B: Mentally distressed							
Age>49	0.431***	0.319**	0.590*	0.075	-0.191**	-0.340**	-0.047
	(0.051)	(0.154)	(0.326)	(0.060)	(0.082)	(0.165)	(0.029)
Bandwidth	12.4	8.6	10.8	8.5	7.8	10.8	8.9
N	3,513	3,224	3,224	20,467	3,224	3,224	20,467

Notes: The outcome variable is an indicator for being vaccinated in column 1, the standardized inverted GHQ Likert score in columns 2-4, and an indicator for being mentally distress at the time of the survey in columns 5-7. In column 1 we report the first stage for the probability of being vaccinated above the 49 years old age threshold. Columns 2 and 5 present reduced form estimations, and columns 3 and 6 show the fuzzy RDD, where vaccination is instrumented using the age threshold. Columns 4 and 7 implement placebo reduced form regressions using information from waves 1-7. The sample includes all respondents in the March 2021 survey, except individuals who are exactly 49, as their vaccination rate (66%) is just in between the level of individuals aged 50-60 (around 94%) and individuals aged 40-48 (around 45%). We also exclude health and social workers, a group which was prioritized and had been vaccinated earlier. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Persistence of the effect

	(1)
Vaccinated in January 2021	0.053
	(0.046)
N	28,948
Sample:	61-80

Notes: The sample includes information from individuals aged 61-80 in waves 1-6 and 8. The outcome variable is the standardized inverted GHQ-12 Likert score. The variable 'Vaccinated in January 2021' takes value 1 for individuals who received their first vaccination before the January 2021 survey wave and zero otherwise. Individuals in the latter group were mostly vaccinated in February and March 2021. Standard errors clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A9: Predictors of Invitations and Vaccinations (1/2)

	(1)	(2)
Outcome variable:	**Invited**	**Vaccinated**
A: Priority groups		
Shielded	0.097∗∗∗	0.085∗∗∗
	(0.029)	(0.021)
Moderate risk	0.051∗∗∗	0.066∗∗∗
	(0.016)	(0.021)
High risk	0.059∗∗	0.076∗∗∗
	(0.027)	(0.027)
Cares for elderly/sick/disabled	0.115∗∗∗	0.119∗∗∗
	(0.021)	(0.027)
B: Individual characteristics		
Mental distress	-0.009	-0.007
	(0.015)	(0.018)
Female	0.019	-0.001
	(0.012)	(0.014)
White	-0.036	-0.022
	(0.034)	(0.034)
Urban	0.012	0.001
	(0.015)	(0.018)
College	0.011	0.026∗
	(0.013)	(0.015)
Living with partner	0.016	0.063∗∗∗
	(0.015)	(0.018)
Parent of children aged 0-15	-0.007	-0.020
	(0.024)	(0.026)
C: Vaccine attitudes and risk perception		
Risk attitude	-0.000	0.001
	(0.006)	(0.007)
Vaccine sceptic in Nov 2020	-0.020	-0.024
	(0.016)	(0.016)
Not concerned with vaccine side effects	-0.028	0.080∗∗
	(0.029)	(0.032)
D: COVID-19 incidence and regions		
COVID-19 cases	-0.003	0.004
	(0.006)	(0.006)
North West	0.066∗∗	0.017
	(0.029)	(0.033)
Yorkshire and The Humber	0.036	-0.020
	(0.026)	(0.036)
East Midlands	0.042	-0.006
	(0.029)	(0.038)
West Midlands	0.047∗	-0.043
	(0.028)	(0.038)
East of England	0.074∗∗	-0.014
	(0.030)	(0.032)
London	0.114∗∗∗	-0.002
	(0.030)	(0.036)
South East	0.036	0.016
	(0.024)	(0.033)
South West	0.014	-0.019
	(0.028)	(0.036)
Wales	-0.098∗∗∗	-0.113∗∗
	(0.035)	(0.046)
Scotland	-0.066∗	-0.110∗∗∗
	(0.035)	(0.041)
Northern Ireland	-0.034	-0.060
	(0.035)	(0.047)

Table A9: Predictors of Invitations and Vaccinations (2/2)

E: Key worker sectors		
Health and social care	0.235***	0.204***
	(0.047)	(0.054)
Education and childcare	0.019	0.076
	(0.060)	(0.073)
Key public services	0.011	0.013
	(0.052)	(0.062)
Local and national government	-0.048	-0.008
	(0.056)	(0.066)
Food and other necessary goods	-0.017	0.019
	(0.046)	(0.058)
Public safety and national security	-0.061	-0.030
	(0.061)	(0.077)
Transport	-0.010	0.048
	(0.059)	(0.071)
Utilities, communications and financial	-0.040	0.009
	(0.055)	(0.065)
F: Occupation sectors		
Agriculture, forestry, fishing	0.029	-0.000
	(0.070)	(0.084)
Mining and quarrying	0.267	0.253
	(0.173)	(0.193)
Manufacturing	-0.055	-0.140**
	(0.045)	(0.063)
Electricity, gas, steam	-0.046	-0.249**
	(0.064)	(0.118)
Water supply, sewage, waste	-0.061	-0.122
	(0.097)	(0.113)
Construction	-0.037	-0.134**
	(0.049)	(0.055)
Wholesale and retail trade	0.007	-0.042
	(0.044)	(0.053)
Repair of motor vehicles, motocycles	-0.160*	-0.225**
	(0.085)	(0.094)
Transportation and storage	-0.023	-0.131**
	(0.059)	(0.065)
Accommodation and food service	-0.022	-0.061
	(0.062)	(0.076)
Information and communication	-0.079	-0.137**
	(0.055)	(0.060)
Financial and insurance activities	-0.021	-0.066
	(0.051)	(0.060)
Real estate activities	-0.012	-0.032
	(0.054)	(0.064)
Professional, scientific, technical	-0.025	-0.065
	(0.046)	(0.054)
Administrative and support service	0.090*	0.041
	(0.054)	(0.060)
Public administration and defence	0.021	-0.039
	(0.050)	(0.061)
Education	0.013	-0.058
	(0.049)	(0.061)
Human health and social work	0.095*	0.017
	(0.049)	(0.055)
Arts, entertainment, recreation	-0.020	-0.071
	(0.069)	(0.078)
Other service activities	0.022	0.003
	(0.046)	(0.053)
Activities of households as employers	0.059	0.058
	(0.100)	(0.102)
Observations	6835	4556

Notes: We report OLS estimates using sample weights and standard errors clustered at the level of strata. In column 1 the sample includes respondents in the January and March 2021 survey waves of 'Understanding Society' and, in column 2, we individuals in these waves who had received an invitation for vaccination. The outcome variable is an indicator for being invited for vaccination in column 1 and an indicator for being vaccinated or having an appointment in column 2. All specifications also include fixed effects for age and survey date. Omitted category: male, non-white, from rural area, without a degree, not living with a partner, not a parent of children aged 0-15 with not applicable industry category from the North East, not a key worker, not clinically vulnerable, not shielding, not caring for vulnerable others, not receiving care and extremely likely to take up the vaccine and unlikely / very unlikely to get COVID19. * (p<0.10), ** (p<0.05), *** (p<0.01)

Table A10: Robustness analysis

	(1) Employment	(2) Regional shocks	(3) Local cases	(4) 5-years	(5) All sample	(6) Balanced	(7) No weights
1st vaccination	0.118***	0.116***	0.129***	0.128***	0.085***	0.068*	0.070***
	(0.037)	(0.036)	(0.038)	(0.046)	(0.028)	(0.036)	(0.022)
Employed	0.133***						
	(0.049)						
COVID-19 cases			-0.014**				
			(0.006)				
N	47,348	47,374	47,172	27,676	66,560	36,530	54,899
Sample	40-80	40-80	40-80	45-55, 65-75	all	40-80	40-80

Notes: The table reports the results of estimating equation (1) using sampling weights and instrumenting vaccination with invitation. The outcome variable is the standardized inverted GHQ-12 Likert score. All regressions include individual fixed effects, age times time event fixed effects, and fixed effects for priority groups interacted with time event and age group dummies. Column 3 allows for time-variant shocks at the regional level. Column 4 introduces the local COVID-19 incidence rate. Column 5 uses a narrower age bandwidth: 45-55 and 65-75, respectively. Column 6 removes any age sample restrictions. Column 7 considers the longitudinal weights for a balanced panel estimation and in column 7 there are no weights. Standard errors clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A11: Attrition

Outcome:	Participation
Vaccination rate	0.195***
	(0.049)
N	120

Notes: Population sample in the COVID-19 survey of Understanding Society, collapsed by wave and age groups in 5-year intervals to match with administrative vaccination uptake data. The outcome variable is the share of people in the age group who have participated in a given survey wave. The vaccination rate is the percentage of people in that age group who have been vaccinated in the week leading up to the survey. The regression includes wave and age groups fixed effects. Bootstrapped standard errors clustered at the level of age groups. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A12: Dimensions of psychological well-being

	(a) Concentration	(b) Lack of sleep	(c) Playing a useful role	(d) Capable of decisions	(e) Constantly under strain	(f) Overcome difficulties
1st vaccination	0.135**	0.023	0.059	0.092	0.087**	0.038
	(0.054)	(0.042)	(0.045)	(0.063)	(0.040)	(0.043)
N	47,376	47,376	47,376	47,376	47,376	47,376
	(g) Enjoy daily activities	(h) Ability to face problems	(i) Unhappy or depressed	(j) Losing confidence	(k) Believe worthless	(l) General happiness
1st vaccination	0.152***	0.062	0.126***	0.133***	0.015	0.135***
	(0.058)	(0.058)	(0.048)	(0.046)	(0.040)	(0.046)
N	47,376	47,376	47,376	47,376	47,376	47,376

Notes: The table reports the results of estimating equation (1) using sampling weights and instrumenting vaccination with invitation. In each cell the outcome variable is a standardized single dimension of the GHQ-12 Likert index. All regressions include individual fixed effects, age times time event fixed effects, and fixed effects for priority groups interacted with time event and age group dummies. Standard errors clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A13: Mechanisms - Vaccine attitudes

	(1) First stage	(2) Reduced form	(3) IV
Outcome:	1st vaccination	Well-being	Well-being
Invited	0.745***	-0.094	
	(0.074)	(0.102)	
No side effects * Invited	0.174**	0.224**	
	(0.073)	(0.110)	
1st vaccination			-0.126
			(0.138)
No side effects * 1st vaccination			0.268*
			(0.145)
N	47,700	47,700	47,700

Notes: All regressions use sample weights and standard errors are clustered at the level of strata. The variable 'No side effects' is an indicator for individuals who did not report any concerns with vaccines' potential side effects in the November 2020 survey wave. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

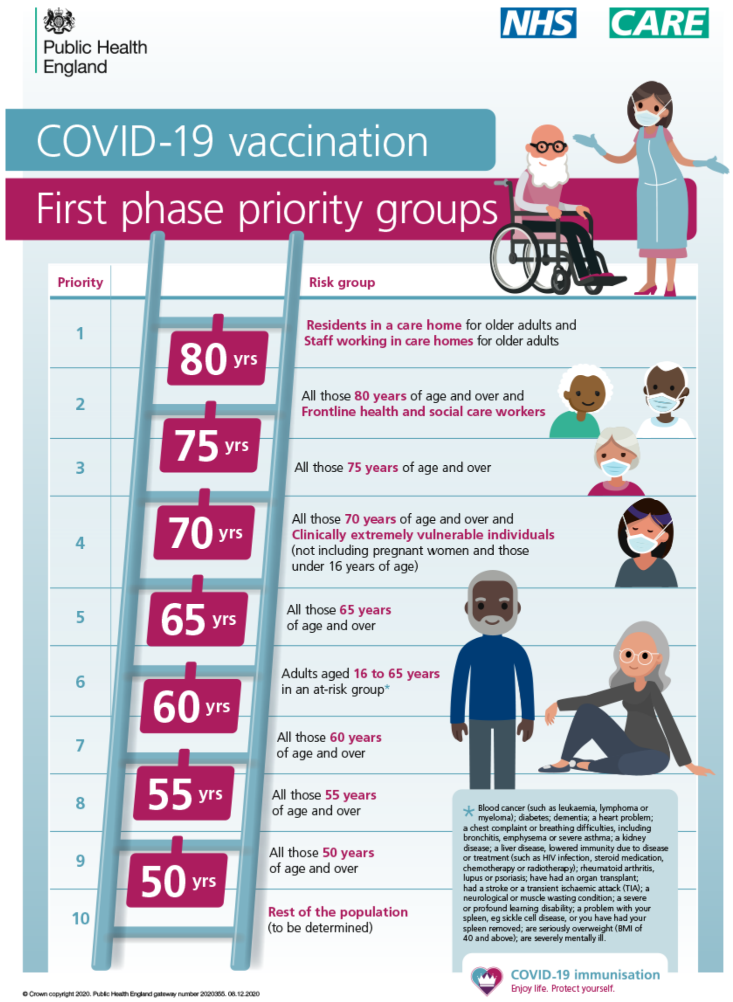
Table A14: Timing of the effect: invitation, appointment and vaccination

Outcome var.:	(1) Psychological well-being	(2) Mentally distressed
Vaccinated	0.152**	-0.018
	(0.068)	(0.036)
Appointment	0.148**	-0.021
	(0.070)	(0.041)
Invited	-0.028	-0.022
	(0.068)	(0.036)
N	47,376	47,376

Notes: The table reports the results of estimating equation (1) using sampling weights and instrumenting vaccination with invitation. In column 1 the outcome variable is the standardized inverted GHQ-12 Likert score, and in column 2 an indicator for being mentally distressed. All regressions include individual fixed effects, age times time event fixed effects, and fixed effects for priority groups interacted with time event and age group dummies. Standard errors clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

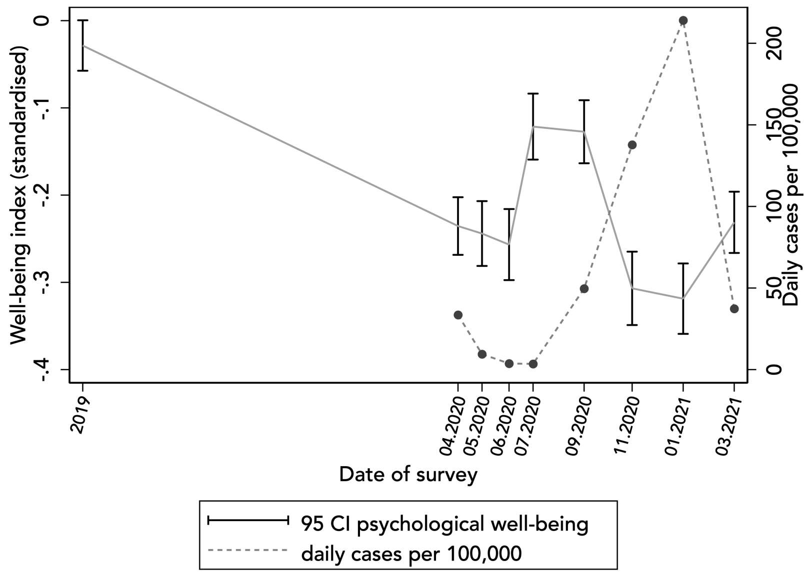
F Appendix: Additional Figures

Figure A1: COVID-19 vaccination roll-out plan of Public Health England



Notes: The priorities for the COVID-19 vaccination programme were established based on the independent report of the Joint Committee on Vaccination and Immunisation (JCVI) of December 30, 2020.

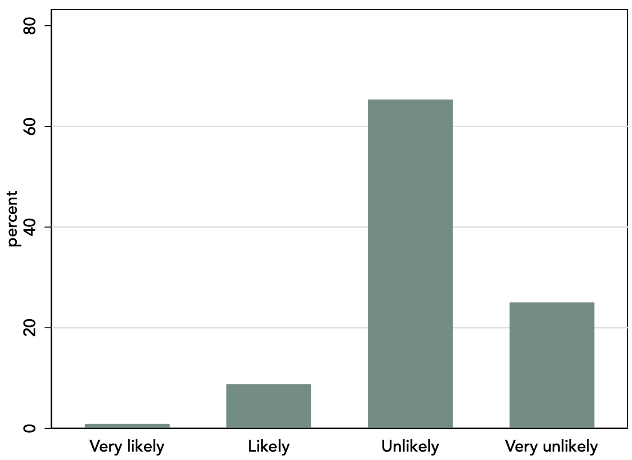
Figure A2: Psychological well-being (GHQ-12) and COVID-19 incidence: 2019-2021.



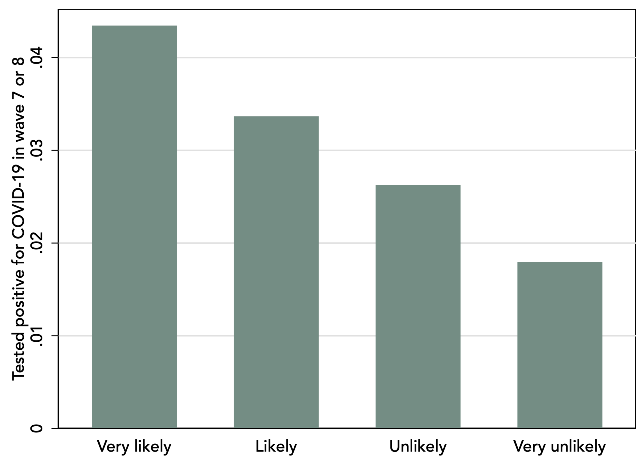
Notes: Population-weighted mean and 95% confidence intervals at survey dates from the main survey and the COVID-19 survey of *Understanding Society*. Information on daily cases from Public Health England.

Figure A3: COVID-19 risk assessment and subsequent probability of testing positive

(a) Perceived COVID-19 risk



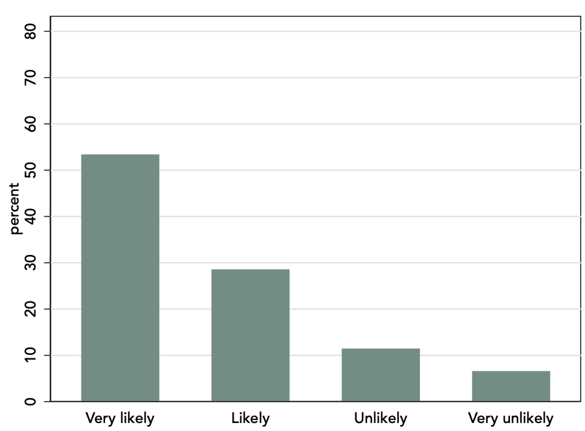
(b) Testing positive by perceived COVID-19 risk



Notes: Population-weighted sample in the COVID-19 survey of *Understanding Society*. In panel (a), perceived COVID-19 risk is measured in wave 6 (November 2020) based on the following question: "In your view, how likely is it that you will contract COVID-19 in the next month?". In panel (b), we show the share of individuals who reported COVID-19 positive test by perceived COVID-19 risk in the previous wave.

Figure A4: COVID-19 vaccine attitudes

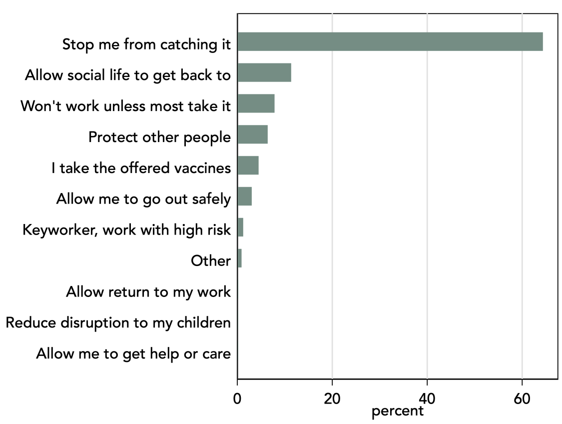
(a) November 2020 (Wave 6), N = 11,853



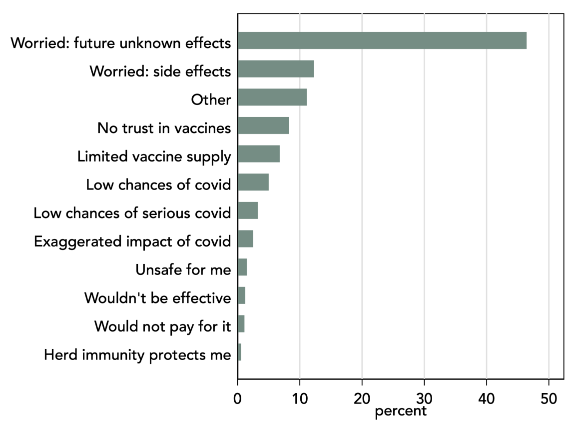
Notes: The table provides population-weighted information on the reply to the question "When you are offered the coronavirus vaccination, how likely or unlikely would you be to take it?". The sample includes all survey respondents in survey waves November 2020, January and March 2021.

Figure A5: Reasons for taking or not taking the vaccine as in November 2020.

(a) What would be your main reason for taking the vaccine?

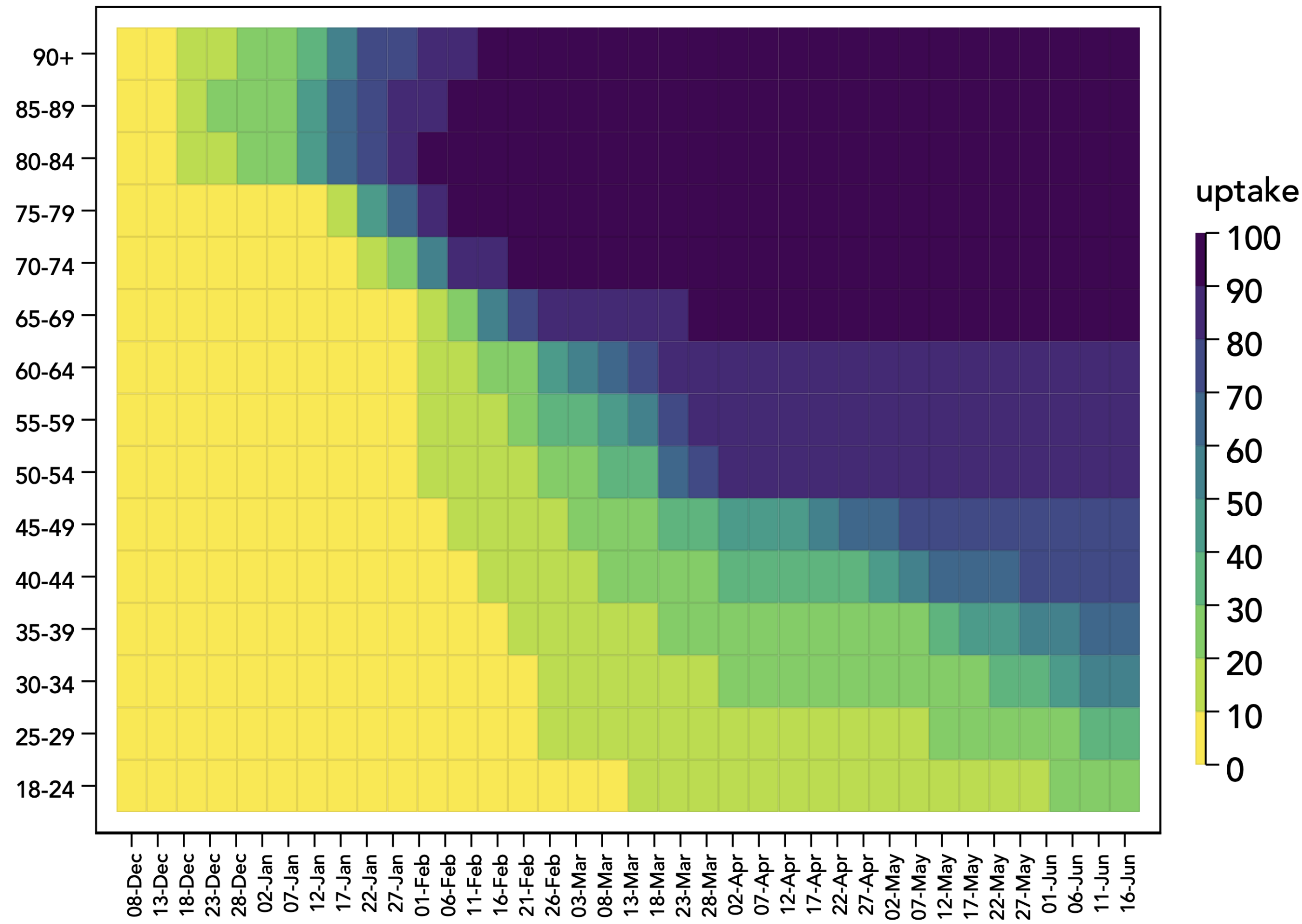


(b) What is the main reason you would not take the vaccine?



Notes: Authors' calculation using data from *Understanding Society* COVID-19 survey. The sample includes respondents aged 40-80, population-weighted in wave 6 (November, 2020).

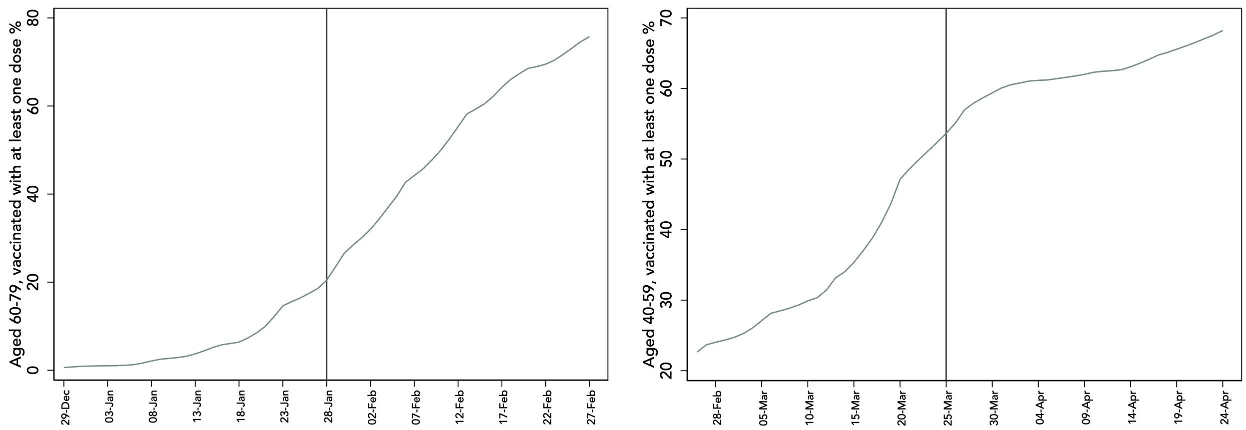
Figure A6: Uptake heatmap of the vaccination roll-out by weeks and within age groups



Notes: Total percentage of people who have received the 1st vaccination, by age group and vaccination date. Source: Public Health England, data from: https://coronavirus.data.gov.uk/

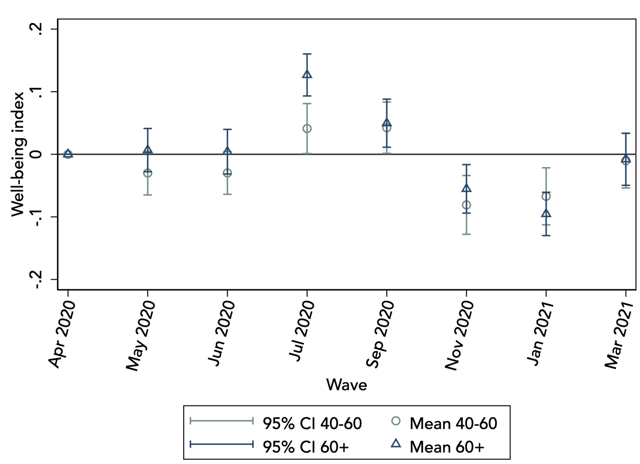
Figure A7: Uptake timeline by age groups.

(a) Cumulative date of vaccination, individuals aged 60-79. (b) Cumulative date of vaccination, individuals aged 40-59.



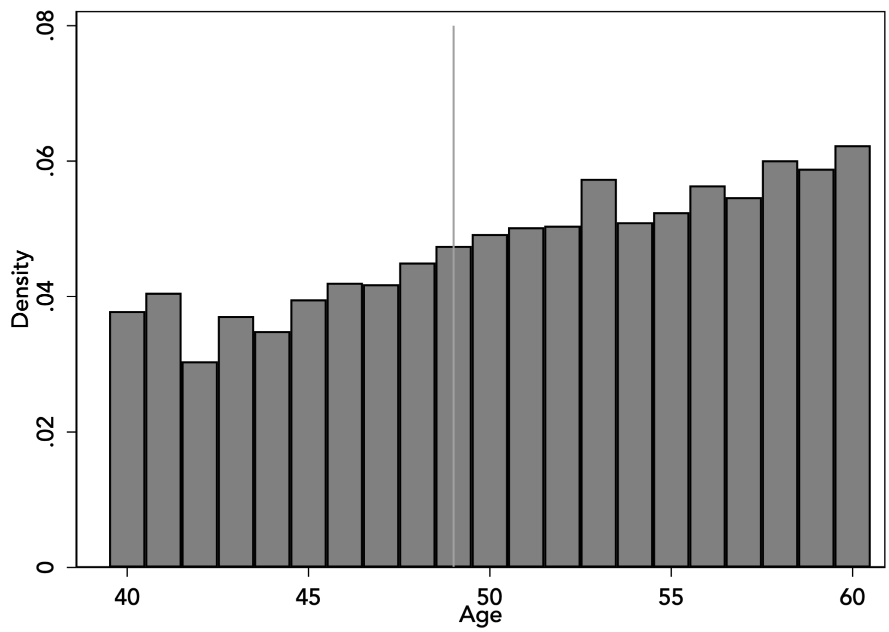
Notes: Proportion of people who has been vaccinated with at least one dose of the vaccine, by date and age group. Source: Public Health England.

Figure A8: Evolution of well-being for different age groups.



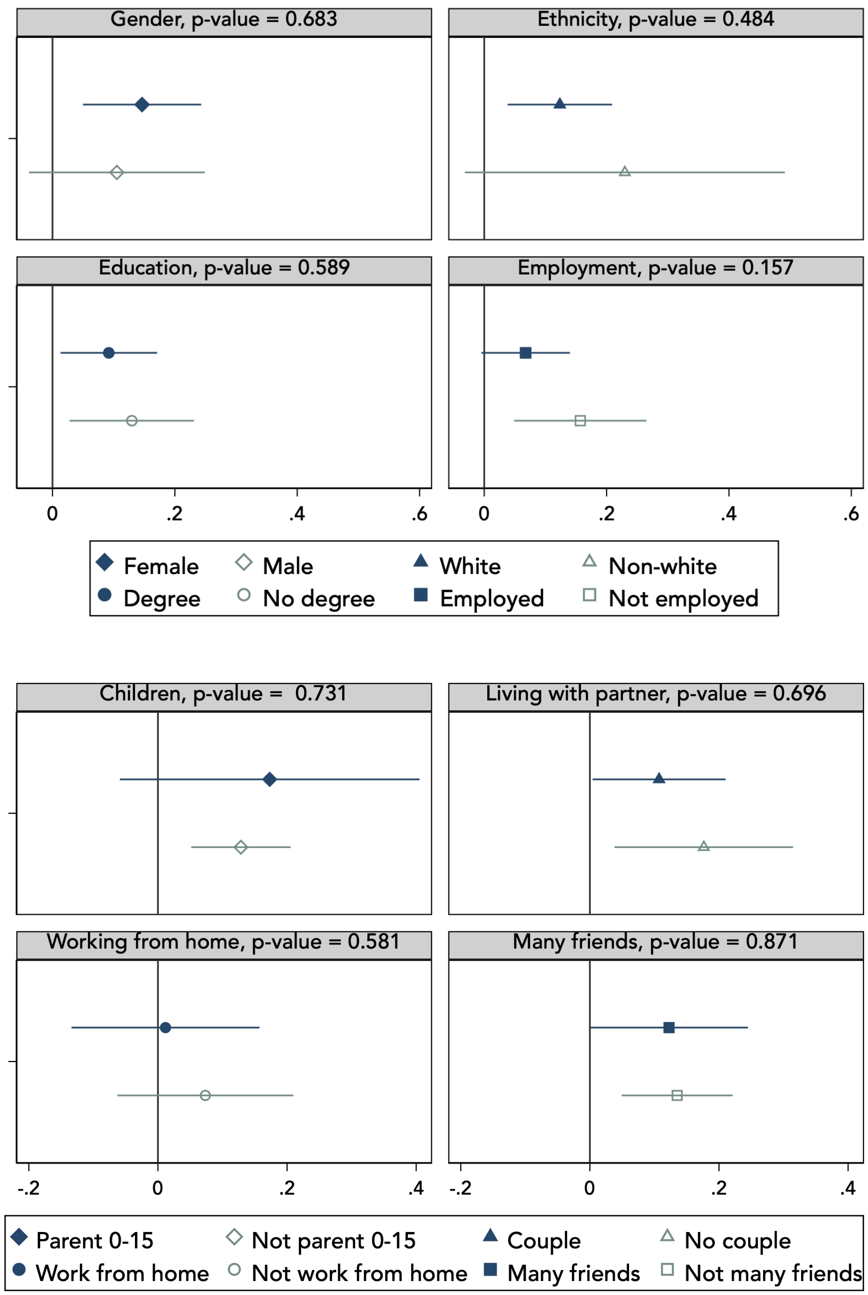
Notes: Authors' calculation, using a OLS regression with individual fixed effects. The omitted group is the April 2020 survey wave and individuals under 40.

Figure A9: Histogram of age



Notes: Histogram of age for individuals in the March 2021 survey wave, excluding health and social workers. The RD manipulation test proposed by Cattaneo et al. (2020) rejects the existence of a discontinuity at the 49 years threshold (p-value=0.93).

Figure A10: Impact of vaccination, by socio-economic group.



Notes: Impact of vaccination on psychological well-being (GHQ-12) for different socio-economic groups. The coefficient plots show the result from the 2SLS estimation of the vaccination on psychological well-being, in sub-samples according to the heterogeneity characteristic. The p-values are derived from a 2SLS estimation of the joint sample with an interaction of the endogenous regressor, the instrument and the fixed effects. Population-weighted sample in the COVID-19 survey of Understanding Society.