The Psychological Gains from COVID-19 Vaccination*

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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 0.12 standard deviations, compensating for one-half of the deterioration in mental health caused by the pandemic. This improvement persists for at least two months, and is linked to higher engagement in social activities and a decrease in the self-reported likelihood of contracting COVID-19. The main beneficiaries are individuals who became mentally distressed during the pandemic, supporting their prioritization in vaccination roll-outs.

Keywords: Psychological well-being, COVID-19 vaccination, instrumental variables and regression discontinuity design.
JEL Classification: I18, I31

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1 Introduction

The COVID-19 pandemic has delivered a profound shock to our lives. In addition to the millions of human lives lost, the pandemic had a strong negative impact on the psychological well-being of the population (Altindag et al., 2022; Banks and Xu, 2020; Belot et al., 2020; Pierce et al., 2020; Proto and Quintana-Domeque, 2021; Proto and Zhang, 2021). For instance, in the UK the average psychological well-being had declined by November 2020 by 0.27 standard deviations compared to pre-pandemic levels, as measured by the 12-item General Health Questionnaire (GHQ-12), 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).

Thanks to the unprecedented speed at which science reacted, by the end of 2020 several vaccines had been developed and cleared by regulators around the world. Clinical trials have shown that these 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 participants are unaware of whether they are receiving the vaccine or a placebo, clinical trials provide limited information on how actual vaccination roll-outs may contribute to the recovery of mental health.

In this paper we exploit the evidence provided by the UK vaccination roll-out to estimate the short-term direct impact of vaccination on psychological well-being. The UK was the first country in the world to start a mass vaccination program in December 2020. 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, their priority group, as well as their psychological well-being, assessed through the GHQ-12. One of the survey waves was conducted in January 2021, when mainly individuals aged 60 to 80 were being invited for vaccination by the National Health Service, and another in March 2021, when the roll-out was reaching mostly individuals between 40 and 60 years old. In our analysis we devote special attention to individuals who had become mentally distressed during the first year of the pandemic, around 16% of the UK population, a group which was not prioritized in the roll-out but which arguably has a larger potential to benefit from vaccination in terms of their mental health.

In order to estimate the causal impact of vaccination on psychological well-being, we use three different empirical strategies that yield broadly similar results. First, taking advantage of the panel structure of the

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

data, we use a difference-in-differences (DID) strategy. We compare the psychological well-being before and after vaccination of vaccinated individuals, using as control group unvaccinated individuals of the same age and priority group. Second, to limit possible endogeneity concerns, we conduct an instrumental variables (IV) analysis, using the timing of invitations for vaccination as an instrument. This analysis exploits the design of the vaccination roll-out in the UK, according to which the timing of invitations was strictly based on individuals' age and priority group. The roll-out prioritized initially front-line health and social workers, in order to protect health systems, and elderly and clinically vulnerable populations, as they have the greatest mortality risk. In our IV analysis we compare individuals who had been invited for vaccination at the time of the survey with other individuals of the same age and priority group who had not been invited yet, plausibly due to the existence of small differences in the speed of the roll-out across different geographical areas. We focus on individuals aged 40 to 80 who are not health or social workers, as for in this group the observed differences in the timing of invitations are more likely to be exogenous. Third, we exploit the regression discontinuity design (RDD) observed in the March 2021 survey around the 49 year old threshold. Just above this threshold more than 90% of individuals were vaccinated at the time of the survey or had an appointment for vaccination, compared to only 50% just below. This gap in vaccination rates is consistent with the design of the vaccination roll-out, which prioritized older individuals.

Overall, our DID and IV estimates are almost identical, up to a large extent reflecting the high compliance rate. Around 95% of individuals who had received an invitation from the NHS were, at the time of the survey, vaccinated or had made an appointment for vaccination. According to our IV results, the first jab improves the GHQ-12 mean symptom score by 0.12 standard deviations (standard error=0.04) 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 induced 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 of moving from unemployment to employment. This average impact is driven mainly by individuals who had become 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). The positive impact of vaccines lasts for at least two months, which is the maximum period that we observe individuals in our dataset. Interestingly, vaccination does not improve the psychological well-being of individuals who had reported in previous waves of the survey that they were concerned with potential unknown side effects of vaccination, around 8% of the population. In this case the impact of vaccination is likely to be, if anything, negative (p.e.=-0.13σ, s.e.=0.14). Unfortunately, we lack statistical

[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.'.

power to estimate the effect of receiving the second jab as only a few hundred people had received their second dose at the time of the March 2021 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.=0.02σ, s.e.=0.08).

We use the rich set of questions available in the survey to investigate the mechanisms through which vaccination improves psychological well-being. Individuals seem to benefit from vaccination through at least two channels. First, vaccinated individuals experience a large decrease in their self-reported probability of contracting COVID-19 during the following month (p.e.=-0.17σ, s.e.=0.06). Second, vaccination improves their social life and their enjoyment of daily activities. Vaccinated individuals are less likely to report that they feel lonely (p.e.=-0.08σ, s.e.=0.04), they are more likely to go for a walk (p.e.=0.15σ, s.e.=0.06) and they are more likely to report that they enjoy normal day-to-day activities (p.e.=0.15σ, s.e.=0.06). The impact is twice as large for individuals who had become mentally distressed during the pandemic, suggesting that socialization played an important role in their recovery. We do not observe any significant impact on self-reported general health or on the probability of contracting COVID-19. The lack of impact on these dimensions is consistent with vaccination requiring several weeks to be effective in preventing infections, and in our analysis most individuals were vaccinated just a few weeks before the survey. Similarly, we do not observe any significant effect on economic outcomes, probably reflecting also the short treatment window considered.

The consistency of our IV estimates relies on the assumption that the differential timing of invitations is not correlated with any time-variant unobserved factors that affect individuals' psychological well-being. A number of robustness tests support the validity of this assumption. An event study analysis shows that the psychological well-being of individuals who had been invited for vaccination at the time of the survey had evolved in the past similarly to non-invited ones of similar age and priority group. We also observe that the timing of invitations is not correlated with local COVID-19 incidence, ruling out that the observed effects are driven by local differences in infection rates. Furthermore, results are unchanged when we allow for time-variant shocks at the regional level, and for a number of alternative sampling restrictions and weighting strategies.

Our estimates are larger but qualitatively similar when we exploit the fuzzy regression discontinuity design observed in the March 2021 survey around the 49 year old threshold. At this age threshold we observe a large discontinuity in the probability of being vaccinated or having an appointment for vaccination (p.e.=43 p.p., s.e.=4), as well as a large improvement in mental health indicators. Individuals above the threshold report higher psychological well-being (p.e.=0.13σ, s.e.=0.07) and their likelihood of being mentally distressed is 10 p.p. lower (s.e.=4). This gap in mental health at age 49 is not observed in previous waves of the survey, suggesting that it is caused by vaccination. Consistent with the results of the IV analysis, the effect is twice as large for the subsample of individuals who were mentally distressed during the pandemic.

Our work speaks to the extensive literature documenting the negative impact of the pandemic on psychological well-being (e.g. Adams-Prassl et al. (2020); Altindag et al. (2022); Etheridge and Spantig (2020); Giuntella et al. (2021); Stantcheva (2021); University of Essex, Institute for Social and Economic Research (2021b). We show that vaccination compensates for around half of the deterioration in mental health caused by the pandemic. We also contribute to a growing literature on the impact of vaccination. While this literature has mainly focused on the impact on physical health, our findings indicate that the impact on mental health is also relevant. There are least three other recent papers examining how vaccination affects mental health, all using US data. Perez-Arce et al. (2021) 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, or to our estimates using a regression discontinuity design.[3] Similarly to Perez-Arce et al. (2021), Koltai et al. (2021) also use data from Understanding America Study and a DID empirical strategy to estimate the impact of vaccination on mental health. Our work is also closely related to a contemporaneous study by Agrawal et al. (2021), who estimate the impact of vaccination on mental health exploiting state-level variation in the timing of vaccinations. Compared to these papers, an important novelty of our work is the focus on individuals who became mentally distressed during the pandemic. We show that the positive impact of vaccination on mental health is driven mainly by this group of individuals. Moreover, our data allows exploring the different mechanisms through which vaccination improves 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). Our results suggest that policy makers may want to take into account mental health for the design of vaccination priority groups.

[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 start a mass vaccination program. The vaccination roll-out was implemented by the National Health Service (NHS), which sent invitations to registered patients using a pre-established priority ordering. 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] Individuals receiving an invitation could schedule an appointment for vaccination, which was implemented mainly by local GPs(JCVI, 2021; UK Department of Health and Social Care, 2021).

Both AstraZeneca and Pfizer/BioNTech were administered, but patients were not informed about which vaccine they would receive before attending their appointment. At the time of the roll-out both vaccines had established effectiveness as announced by Public Health England's vaccine surveillance reports. The system did not allow to get an appointment without an invitation letter or to be vaccinated without an appointment.

The beginning of the roll-out in December 2020 coincided in time with a new wave of the pandemic, which led to the introduction of the third national lockdown on 6 January 2021. The population was requested to stay at home and they were not allowed to meet indoors with people from other households. The lockdown rules were uniform across different areas of the country. Following the decline in the infection rate, on February 22 a road-map 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.

Table A1 provides information on the main summary statistics for the adult population in the survey (columns (1)-(4)). The composition of this sample mirrors the adult UK population. Around 53% are

[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)

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. In our main analysis we focus on individuals between 40 and 80 years old, excluding health and social workers (see columns (5) and (6)). More detailed information about the definition of the main variables is available in Table A2.

3.1 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 mainly 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 for the first jab 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 whether individuals were 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%).[5] Furthermore, approximately 10% of the population report having received a message 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, approximately 9%.

Attitude towards vaccines In the survey wave that was conducted in November 2020, just before the beginning of the vaccination roll-out, 18% of individuals report that they are unlikely or very unlikely to vaccinate (see Figure A2). The main concern for non getting vaccinated was the possible existence of unknown side-effects. Among survey respondents willing to be vaccinated, their main motivations for getting the jab are to avoid catching COVID-19, to recover social life and to protect other people (see Figure A3). The share of people unwilling to vaccinate decreased over time as the roll-out was implemented. By March 2021 only 5% of respondents were reluctant to vaccination.

[5] 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, 2021a).

3.2 Psychological well-being: general health questionnaire

Psychological well-being is measured using the General Health Questionnaire (GHQ-12), a screening tool commonly used to detect current state mental disturbances and disorders in primary care settings (Goldberg and Hillier, 1979). The GHQ-12 twelve 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 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 A4, during the first months of the pandemic, mental health measures deteriorated dramatically. In April 2020 the average psychological well-being, as measured by the *mean symptom score*, 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.

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

3.3 Physical health and COVID-19

Survey participants report their general health on a Likert scale. Around 48% consider that their health is excellent or very good, and only 4% report having poor health.

About 5% of respondents declare having experienced in the previous one or two months COVID-19 symptoms that could have been be caused by coronavirus, and 2% report that they have tested positive in a COVID-19 test. Survey respondents are also asked about their expected likelihood of contracting COVID-19. 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 A5 (a)). The self-reported risk of contracting COVID-19 is positively correlated with 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 A5 (b)).

Interestingly, the perceived risk decreases monotonically with age. 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.

3.4 Daily activities

We use three proxies for the intensity of social interactions and the enjoyment of daily activities. 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. 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.

3.5 Labor market and household finances

Around 60% of individuals are employed and 36% work from home always or often. On average, they work 28 hours a week and household weekly income is around GBP 650 (USD 900). Approximately two thirds of 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 previous 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.[6]

[6] 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').

3.6 Additional data sources

We complement the information provided by the survey with information on COVID-19 incidence at the local level, as measured by the daily number of COVID-19 positive tests per 100,000 inhabitants in the corresponding Middle Layer Super Output Areas (MSOAs). The average MSOA includes around 4,000 households.

We also collected administrative data from Public Health England on the percentage of people who received the 1st COVID-19 vaccination over time by age group. As shown in Figure 1, once the roll-out reached a cohort, it took just a few weeks to complete its vaccination. For instance, individuals aged 75-79 started to be vaccinated in mid-January and by mid-February their vaccination had been completed.

4 Empirical Analysis

4.1 Factors predicting invitations and vaccinations

Invitation for vaccination We start by examining the factors that predict whether an individual has been invited for vaccination at the time of the survey. The purpose of this analysis is to verify that the timing of invitations was consistent with the official guidance of the NHS.

As expected, we observe a strong age gradient (see Figure 2). 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.

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

$$y_{it} = \sum_{a=41}^{80} \alpha_a \cdot I(a = age_i) + \beta \cdot I(t = March_{2021}) + X_{it} \cdot \gamma + \epsilon_{it} \tag{1}$$

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 A3, column (1). As expected, members of priority groups are. more likely to have been invited for vaccination. The probability of receiving an invitation is largest for health and social care keyworkers (24 p.p). We also observe higher rates for other priority groups: carers (11 p.p.), clinically extremely vulnerable individuals (6 p.p.), 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).[7] As we discuss in more detail below, this result supports our IV identification strategy, which relies on the exogeneity of the timing of vaccination invitations for individuals of the same age and priority group.

Vaccination Next we study which factors affected the decision of getting vaccinated. We estimate equation (1) for the sample of individuals who received an invitation, using as outcome variable a dummy that takes value one if individuals have received their first vaccine dose or made an appointment, and zero if individuals received an invitation but failed to make an appointment.

The immense majority of people invited for invitation, around 95%, got vaccinated or were waiting for an appointment at the time of the survey. As shown in Table A3, column (2), vaccination rates are significantly higher among priority groups and among individuals living with a partner. Not surprisingly, individuals who had reported in a previous survey wave that they were concerned with the potential existence of vaccination unknown side effects are less likely to vaccinate, but the gap is relatively small (8 p.p.). We observe also some differences by geographic area, but we do not observe any significant correlation between vaccination rates and COVID-19 incidence at the local level. Similarly, we do not observe that previous mental distress in any way predicts vaccination.

[7] According to the 95% confidence interval, 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.

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. The section is structured as follows. First, we estimate the impact of vaccination using 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 variable (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. Seventh, 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. Finally, we examine the persistence of the observed positive effect on mental health, tracking individuals for two months until the following survey wave.

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. 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). As shown in Figure 3, 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, implying that we are comparing 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, but would be vaccinated in a few weeks. More precisely, we estimate the

[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.

following equation:

$$
\begin{aligned}
y_{it} = & \sum_{j \in \text{sample}} \alpha_j \cdot I(j=i) + \sum_{e=-6}^{1} \sum_{a=40}^{80} \beta_{e,a} \cdot I(e=t) \cdot I(a=age_i) + \\
& + \sum_{e=-6}^{1} \sum_{p} \sum_{g} \lambda_{e,p,g} \cdot I(e=t) \cdot I(p=prioritygroup_{it}) \cdot I(g=agegroup_{it}) + \gamma \cdot \text{Vaccinated}_{it} + \epsilon_{it}
\end{aligned}
\tag{2}
$$

where we denote 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 our main independent variable, $Vaccinated_{it}$, 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 A6).[10] Finally, we also 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 specific priority groups. The remaining sample includes around 48k observations corresponding to 8k different respondents. As shown in section 4.2.5, these sample restrictions do not affect our results.

In Table 1, we report the results from estimating equation (2) 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

[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,

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

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.=0.05σ (s.e.=0.02), indicating that vaccinated individuals are positively selected in terms of their underlying psychological well-being. This positive selection reflects up to a large extent that vaccinated individuals 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 between November 2020 and January 2021, individuals above 60 experienced a deterioration of their psychological well-being relative to other age groups, perhaps due to their larger sensitivity to lockdown measures and to an increase 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 (2), allowing also for different priority groups being exposed to different time-variant shocks. This additional set of controls leaves the estimate unchanged (p.e.=0.13σ, s.e.=0.03).

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. To explore the plausibility of this hypothesis we conduct an event study analysis and we estimate the following equation:

$$\begin{aligned} \mathrm{y}_{it} = & \sum_{j \in \text{sample}} \alpha_j \cdot I(j=i) + \sum_{e=-6}^{1} \sum_{a=41}^{80} \beta_{w,a} \cdot I(e=t) \cdot I(a=age_i) + \\ & + \sum_{\substack{e=-6 \\ e \neq 0}}^{1} \gamma_k \cdot I(e=t) \cdot treatmentgroup_i + \epsilon_{ite} \end{aligned} \tag{3}$$

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 4, 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. 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 (2) using the timing of invitations as an instrumental variable for vaccination. More precisely, our instrument takes value one if the individual had received an invitation at the time of the survey and zero otherwise. As shown in column (5) of Table 1, the IV estimate is slightly less precise but the point estimate is unchanged (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 and 40-60. The impact of vaccination is practically identical for both groups.

So far we have used as outcome variable the (inverted) standardized GHQ-12 mean score. In Table A4 we reproduce the previous analysis using as an outcome variable an indicator for being mentally distressed (i.e. the caseness indicator). According to the IV estimation (column 4), vaccination decreases the probability of being mentally distressed by 4.3 p.p. (s.e.=2.1 p.p.).

Exogeneity The validity of the IV strategy requires the exogeneity of the instrument, conditional on controls. In this particular context, given that the underlying identification relies on a DID specification, this assumption is equivalent to the standard DID parallel trends assumption, which 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 investigate the plausibility of this assumption, we conduct an event study analysis and we estimate equation (3) including in the treatment group individuals that were invited for vaccination and in the control group all other individuals of the same age and priority group. As shown in Figure A7, results confirm that invited and non-invited individuals had evolved similarly in the past, supporting the exogeneity of the instrument.

Exclusion restriction In addition to the exogeneity assumption, the consistency of the IV estimator 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.

Monotonicity condition 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 plausible.

4.2.3 Mechanisms

Individuals report in the survey that their main motivation for getting vaccinated is to protect their health, recover their social life, and get back to work, while their main concern against is the possibility of future unknown side effects. We explore the role played by these factors in explaining the observed 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. There is no significant effect on the probability of having had symptoms of COVID-19 during the month prior to the survey or testing positive, and we only observe a marginally significant impact on self-reported general health (see Table 2). This lack of significant estimates 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 vaccination seems to have little impact on physical health at the time of the survey, it has a strong effect on expectations about future health. It decreases individuals' expected probability of contracting COVID-19 during the following month by 0.17σ (s.e.=0.06), confirming that the population expected vaccines to be effective.

Social interactions and daily activities Another factor that seems to mediate the impact of vaccination on psychological well-being is the improvement in social life and daily activities (see Table 2). 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 Finally, we do not observe any significant effect on labor market outcomes, saving behavior or consumption (see Table A5). 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, on average, vaccination has a significant positive impact on psychological well-being. Next, we investigate whether this effect is larger for the subset of individuals who had become mentally distressed during the pandemic. Given that their psychological well-being was more sensitive to COVID-19, it is plausible that they benefit relatively more from vaccination. More precisely, we focus on individuals who were not mentally distressed in January 2020, before the start of the pandemic, but report being distressed in September 2020, before the vaccination roll-out. We estimate equation (2) allowing for an interaction between vaccination and an indicator variable for this group of individuals, 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 (becoming distressed between January and September 2021) is predetermined relative to our measure of psychological well-being as an outcome variable.

We report these results in Table 3. As shown in column (1), the positive impact of vaccination is 3.3 times larger for individuals who became distressed during the pandemic (0.39σ vs. 0.11σ). The impact is also significantly stronger when we consider as the outcome variable a dummy for being mentally distressed. For the group of individuals who became distressed during the pandemic, vaccination decreases the probability of being mentally distressed in January or March of 2021 by 17 p.p. (s.e.=5), compared to an effect of merely 3.5 p.p. (s.e.=2.8) for the rest of the population (column (3)). In columns (2)-(4) we verify whether these large effects also hold for individuals who were distressed already before the pandemic. In this case we do not observe any additional impact from vaccination, suggesting that distressed people benefit more from vaccination when their psychological problems were linked to the pandemic.

In columns (5)-(7), we investigate the possible mechanisms for this stronger effect. We do not observe any differential impact on the perceived risk of contracting COVID-19. However, individuals who became distressed during the pandemic seem to benefit more in terms of their social interactions. They experience a larger decrease in self-reported loneliness and a larger increase in their enjoyment of daily activities.[12]

So far we have identified individuals whose mental health was negatively affected by the pandemic using a dychotomic variable. We investigate further how the impact of vaccination varies depending on how much individuals were impacted by the pandemic using a more granular measure. In particular, we compute the variation in the *GHQ-12 mean score* experienced by individuals between January 2020 and September 2020, and we group individuals in 10 categories of roughly similar size according to this measure, such that group 1 includes individuals who experienced the largest deterioration in their *GHQ-12 mean score* and group 10 individuals who experienced the largest improvement.

In Figure 5, we report a coefficient plot of the impact of vaccination on psychological well-being for each one of these groups. The impact of vaccination is roughly similar for all groups except for the bottom decile, where the effect is three times as large, around 0.42σ. In sum, the 10% of individuals whose psychological well-being was most negatively affected by the pandemic benefit disproportionately from vaccination.

4.2.5 Robustness

As we show below, our results are robust to the inclusion of a number of additional controls, including the local COVID-19 incidence rate, allowing for time-variant shocks at the regional level, for changes in the sample composition, and alternative survey weights. Furthermore, we do not observe any evidence suggesting that vaccination affected participation in the survey.

Additional controls In column (1) of Table A6, we estimate our preferred specification, i.e. equation (2) using invitations as an instrument for vaccination, and including also a dummy that takes value one if individuals are employed. As expected, including employment as an additional 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. Results are also unchanged when we control for the local incidence of COVID-19 at the time of survey (column (3)). This variable is negatively correlated with psychological well-being but, as shown in

[12] We do not consider here the variable *weekly walking*, as it is available only in two waves.

section 4.1, it 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 larger than 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:

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

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.

In this equation the coefficient γ captures any potential impact of vaccination on individuals' participation in the survey. As shown in Table A7, the estimate is small and insignificant (p.e.=0.23, s.e.=0.14). There is no correlation between the share of individuals in a given age group who were vaccinated just before the survey wave and the probability that they participate in the survey.

4.2.6 Extensions

We 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 investigate whether there is any anticipation effect. 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 using information from a few hundred people who had received it by the time of the March 2021 survey, but results are imprecise and inconclusive.

Dimensions of the GHQ-12 index The GHQ-12 index aggregates information from 12 different questions. In Table A8 we estimate the impact of vaccination separately for each question. 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 0.10σ.

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 A8).

Attitude towards vaccines The fear of future unknown side-effects might mediate the impact of vaccines on psychological well-being. We estimate our IV equation allowing for an interaction between vaccination and a dummy variable that takes value one for individuals who reported in the November 2020 survey that they were not concerned with side-effects and value zero otherwise. In column (1) of Table A9 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, where 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). Our results suggest that vaccine hesitancy undermines the psychological benefits of the vaccination roll-out.

Timing of the effect In the survey we can observe individuals at 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 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 (2). As shown in Table A10, 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). In column (2) we report results from a similar estimation using as outcome variable a dummy for individuals who are *mentally distressed*, although in this case estimates are generally insignificant. The existence of a large positive effect on psychological well-being 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. Given the age profile of these individuals, we focus the analysis on the sample of individuals older than 60. Practically all of them (around 98%) had received their first jab and 6% had received also their second jab. As shown in column (8) 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 first jab.

4.2.7 Regression discontinuity design

We also estimate the impact of vaccination exploiting the fuzzy 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.[13] Just above age 49, around 90% of individuals are vaccinated or have made an appointment for vaccination, 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. An advantage of using a RDD is that

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

it relies on weaker assumptions than the DID and the 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, the RDD has more limited statistical power, as it exploits only information for individuals around the threshold, and its estimates are local.

We estimate the following first-stage, reduced-form and fuzzy RDD equations using information from the March 2021 survey wave:[14]

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

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

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

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 - first stage); 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, in the second and third equations 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.

First we examine the data using RD plots. As shown Figure 6), a clear discontinuity is observable at the cutoff both in terms of the probability of being vaccinated (upper panel) and individuals' probability of being mentally distressed (lower panel). The discontinuity in psychological well-being is driven by individuals who were mentally distressed during the pandemic. In Table 4 we quantify the size of these gaps. As shown in the upper panel, column (1), the first stage estimation (equation 5.a - first stage) shows that being above 49 years of age increases the probability of being vaccinated or having an appointment at the time of the March survey by 45 p.p. (s.e.=3). In column (2) we report the reduced form estimates (equation 5.b - reduced form), which show that individuals above this threshold have 0.13σ (s.e.=0.07) higher psychological well-being and, according to the fuzzy RDD estimates (equation 5.c - fuzzy), vaccination increases psychological well-being by around 0.30σ (s.e.=0.17) (column (3)). Our estimates are qualitatively similar and more precise when we

[14] We exclude from the estimation individuals who are exactly 49, as their invitation rate (48%) is just in between the level of individuals aged 50-60 (around 95%) and individuals aged 40-48 (around 47%). We also exclude Health and Social workers, a group which was prioritized and had been vaccinated earlier.

use as an outcome variable a dummy for being mentally distressed (columns (5) and (6)). 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). In the lower panel of Table 4 we conduct the same analysis restricting the sample to individuals who report 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.

The validity of the RDD analysis is supported by several robustness tests. The placebos reported in columns (3) and (7) show that the gaps observed at the 49 years threshold did not exist in previous waves. Furthermore, the age density function does not exhibit any discontinuity at the 49 years threshold (Figure A9). The fuzzy RDD estimates tend to be twice as large as the DID-IV estimates, although they are imprecise and the difference is not statistically significant. A possible explanation for this difference is that each approach identifies the impact on a different segment of the population. In the 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 49 years threshold. The identity of 'compliers' also differs. The 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 have been different if they were slightly younger or older.

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 vaccinated respondents, between January and March 2021. More precisely, we compare the well-being at the end of March 2021 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 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 A11, 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 individuals who became mentally distressed during the pandemic, who account for around one sixth of the adult population. Our results suggest that it might be advisable to prioritize this group in vaccination roll-outs. It would lead to a faster improvement in the psychological well-being of the population and, moreover, since mentally distressed people tend to have significantly higher utilisation rates of the health system, it might help to ease the pressure on the health. For instance, according to our data mentally distressed people are 50% more likely to use outpatient and inpatient services.[15] Overall, our results strongly suggest that policy-makers may want to consider mental health for the design of priority groups.

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 potentially important indirect channels such as the positive externality provided by other individuals' vaccination. Second, our analysis identifies the short-term effect 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. Third, our results may be subject to a downwards bias if individuals experience anticipation effects before being invited for vaccination, as this would increase the psychological well-being of the control group. In this case our results should be interpreted as a lower bound of the actual effect. Fourth, if vaccination roll-out policies were to be based on stated mental health factors, there is the risk that some people falsely represent their mental health to jump the queue. Finally, 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.

[15] In wave 6 of the survey 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 mean 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: 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 (2), 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 3: Impact of vaccination on individuals who became mentally distressed during the pandemic

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Outcome:	Well-being	Well-being	Distress	Distress	Perceived risk	Loneliness	Daily activities
1st vaccination	0.120*	0.119*	-0.035	-0.034	-0.279***	-0.103**	0.109
	(0.062)	(0.061)	(0.028)	(0.028)	(0.057)	(0.042)	(0.068)
1st vaccination * distressed during COVID-19	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)	(0.107)
1st vaccination * distressed before COVID-19		0.013		-0.016			
		(0.083)		(0.034)			
N	14,238	14,238	14,238	14,238	14,146	14,232	14,238

Notes: In all columns we report estimates of equation (2), instrumenting the 1st vaccination with invitation, using sample weights and with standard errors clustered at the level of strata. The sample includes information from survey waves in November 2020, January 2021 and March 2021. 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 dummy variable *distressed during COVID-19* takes value one for the sample of individuals who were mentally distressed in September 2020 but not in January 2020. The dummy variable *distressed before COVID-19* takes value one for all individuals who reported being mentally distressed in January 2020. The outcome variable is the standardized inverted GHQ-12 mean score in columns (1) and (2), an indicator for being mentally distressed in columns (3) and (4), the (standardized) risk perception in column (5) (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 (6) (based on question: "how often one feels lonely: hardly ever or never/some of the time/often" and enjoying daily activities in column (7), which is one of the GHQ-12 dimensions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

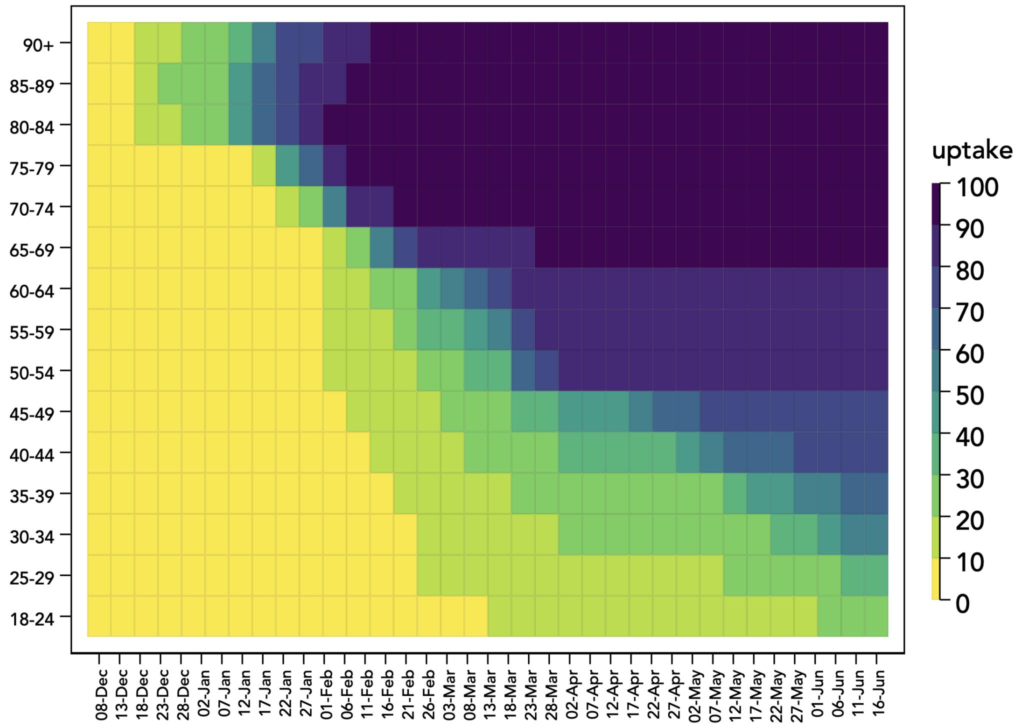
Table 4: Regression discontinuity design

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	First stage	RDD	Fuzzy RDD	Placebo	RDD	Fuzzy RDD	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	0.432***	0.132*	0.296*	-0.017	-0.101***	-0.198**	0.014
	(0.039)	(0.073)	(0.166)	(0.024)	(0.037)	(0.077)	(0.011)
Bandwidth	7.5	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 before vaccination							
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 mean 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). In colums (1)-(3) and (5)-(6) 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figures

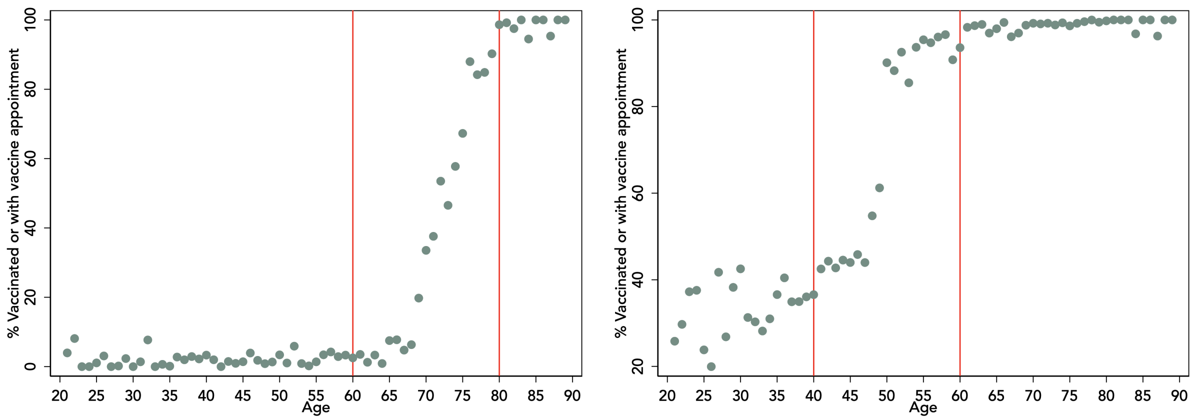
Figure 1: Uptake heatmap of the vaccination roll-out by weeks and within age groups



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 2: Vaccination rate by age.

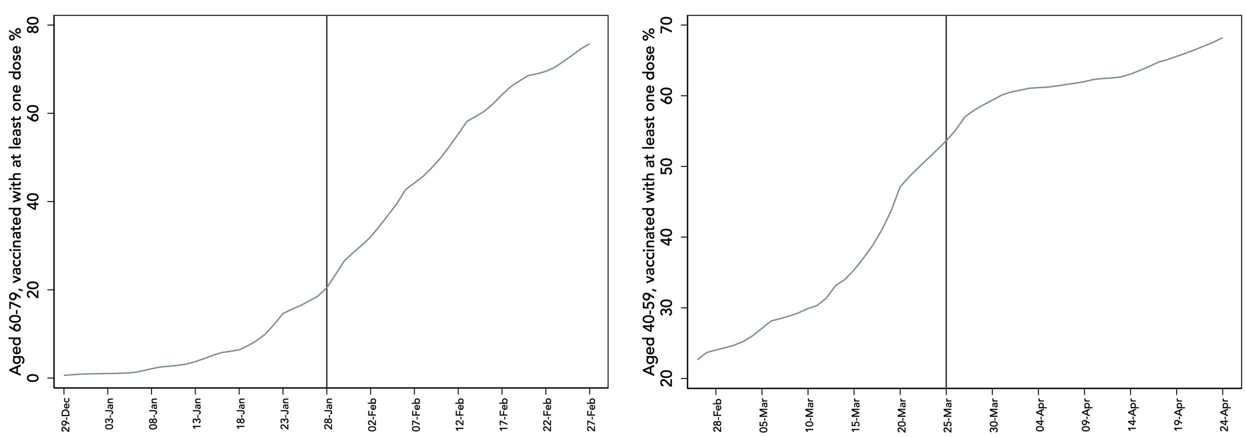
(a) 27 January 2021 (survey wave 7) (b) 24 March 2021 (survey wave 8)



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*.

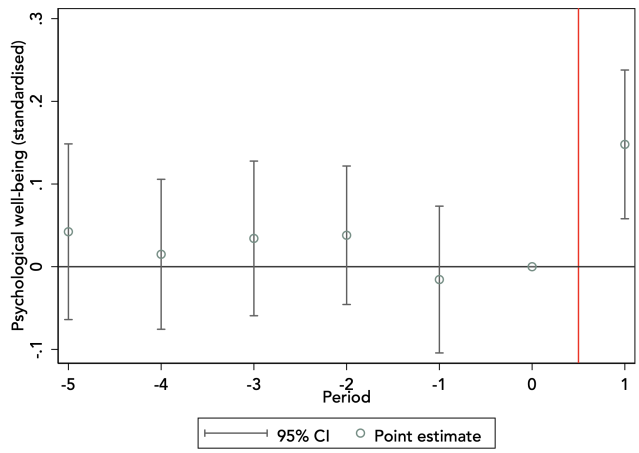
Figure 3: Uptake timeline by age groups.

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



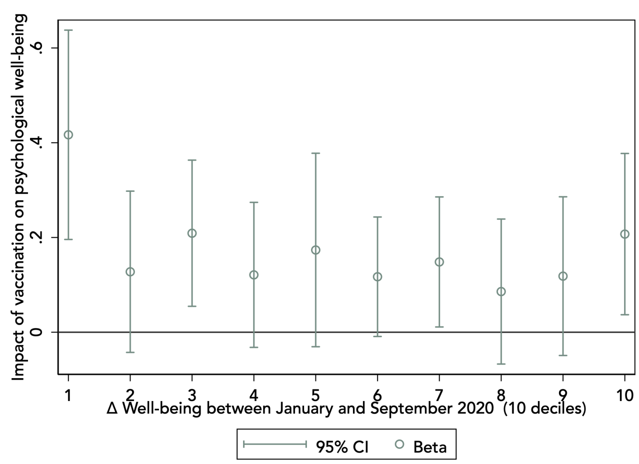
Notes: Proportion of people who has been vaccinated with at least one dose of the vaccine, by date and age group. Source: Public Health England.

Figure 4: Event study - Impact of vaccination on psychological well-being



Notes: The figure reports the estimates from an event study analysis using equation (3). 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.

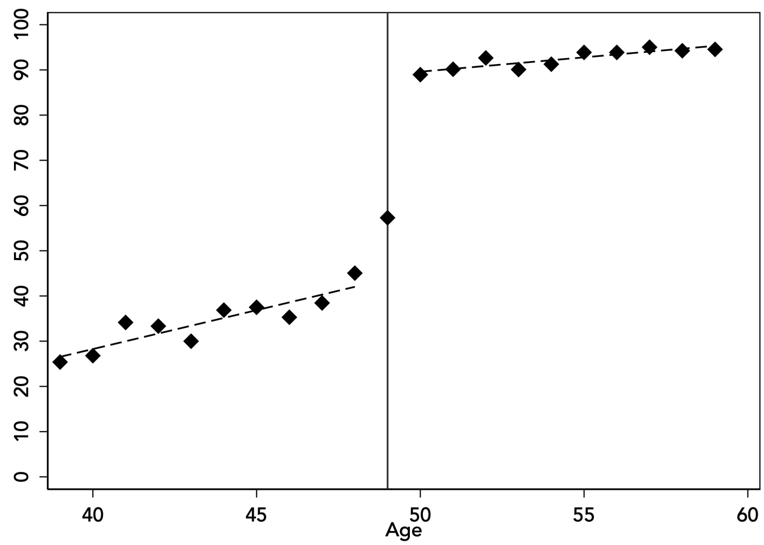
Figure 5: Impact of vaccination on psychological well-being, by the variation in psychological well-being experienced during the pandemic.



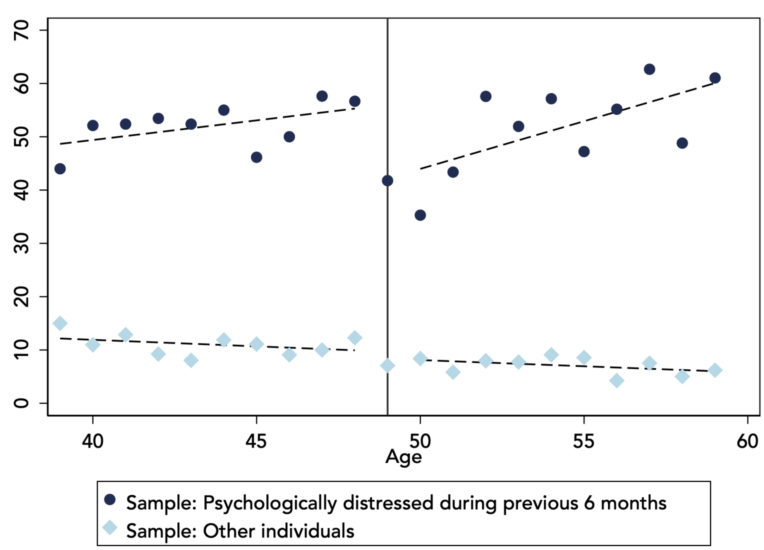
Notes: Coefficient plot of the impact of vaccination on the standardized and inverted GHQ-12 mean score. In the X-axis, individuals are classified in 10 groups, based on how their *GHQ-12 mean score* evolved between January 2020 and September 2020. The *GHQ-12 mean score* of individuals in group 1 decreased between -36 and -7 (10% of the sample), in group 2 by -4, -5 or -6 (11%), in group 3 by -3 (7%), in group 4 by -2 (9%), in group 5 by -1 (11%), in group 6 there was no change (16%), in group 7 it improved by 1 (10 %), in group 8 by 2 (7%), in group 9 by 3 or 4 (8%), and in group 10 by between 5 and 36 (12%).

Figure 6: Regression discontinuity plots

(a) Vaccination rate by age (%), 24-31 March 2021.



(b) Psychologically distressed (%), 24-31 March 2021.



Notes: In sub-figure (a) the sample includes individuals aged 39-59 who participated in the 2021 March survey of *Understanding Society*. Sub-figure (b) provides information separately for individuals who reported being psychologically distressed during the previous six months and for other individuals. Both plots omit individuals in health and social care occupations. The vaccination rate includes also individuals with an appointment for vaccination.

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 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: All descriptive statistics and analysis are performed using the weights, stratification and clustering defined by *Understanding Society*. Columns (1)-(4) provide information for all adult survey respondents in waves 1-8 of the *Understanding Society* COVID-19 survey. Columns (5) and (6) provide 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 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 COVID-19	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: 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 A3: 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), 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 A4: 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 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 (2), 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: 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 (2) instrumenting vaccination with invitation. The outcome variable is the standardized inverted GHQ-12 mean 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 (2) includes a set of dummies of regions interacted with survey wave (e.g. *'North East * January 2021'*. Column (3) introduces the local COVID-19 incidence rate. Column (4) uses a narrower age bandwidth: 45-55 and 65-75, respectively. Column (5) removes any age sample restrictions. Column (6) considers a balanced panel with longitudinal weights. We used sampling weights in all regressions except in column (7). Standard errors clustered at the level of strata. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Attrition

Outcome:	Participation
Vaccination rate	0.195
	(0.133)
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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8: 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 (2) using sampling weights and instrumenting vaccination with invitation. In each cell the outcome variable is one of the (standardized) 12 items of the GHQ-12. 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 A9: 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' future unknown side effects in the November 2020 survey wave. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A10: 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 (2) using sampling weights and instrumenting vaccination with invitation. In column (1) the outcome variable is the standardized inverted GHQ-12 mean 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

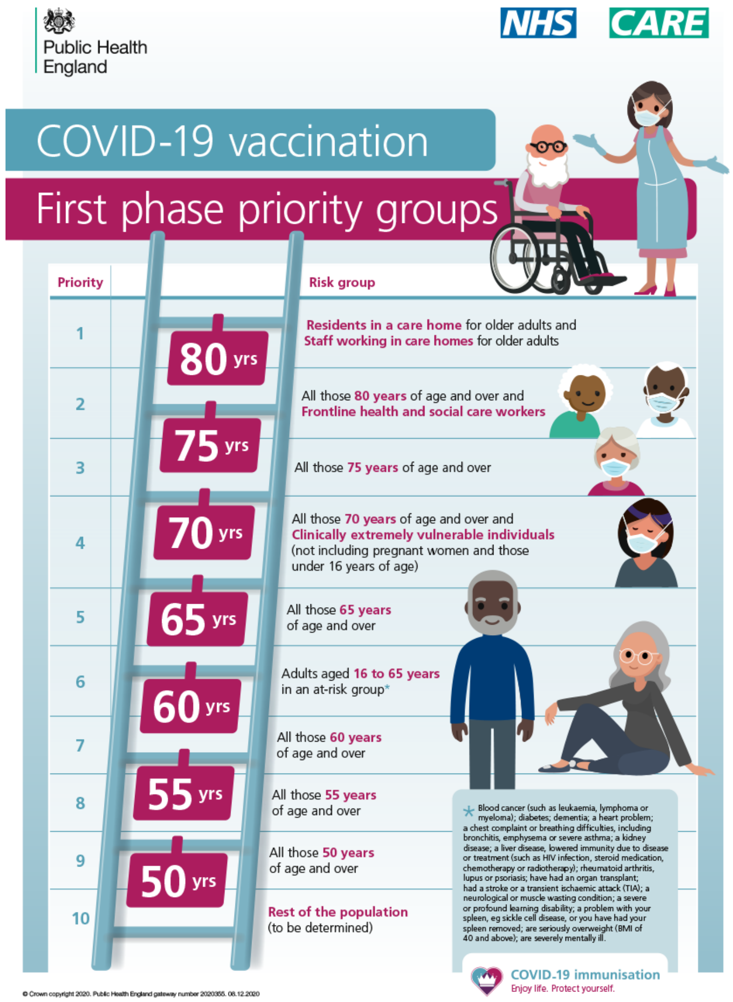
Table A11: Persistence of the effect

	(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 mean 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

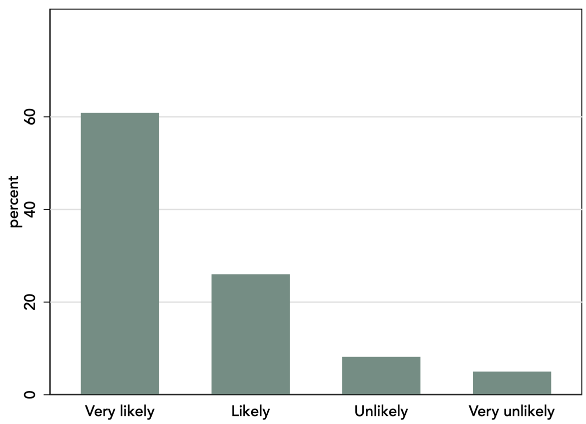
C Appendix: Additional Figures

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.

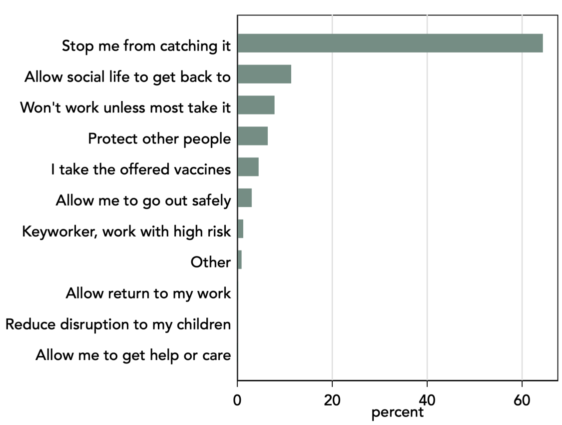
Figure A2: When you are offered the coronavirus vaccination, how likely or unlikely would you be to take it?



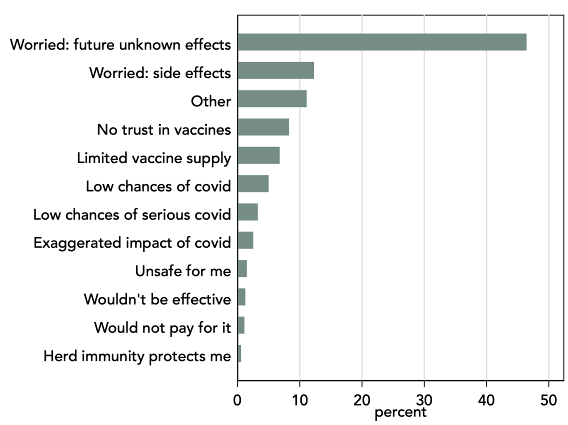
Notes: Authors' calculation using data from *Understanding Society* COVID-19 survey. The figure provides population-weighted information on the reply to the question "When you are offered the coronavirus vaccination, how likely or unlikely would you be to take it?" in survey wave November 2020 (N = 11,853).

Figure A3: Reasons for taking or not taking the vaccine, November 2020.

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

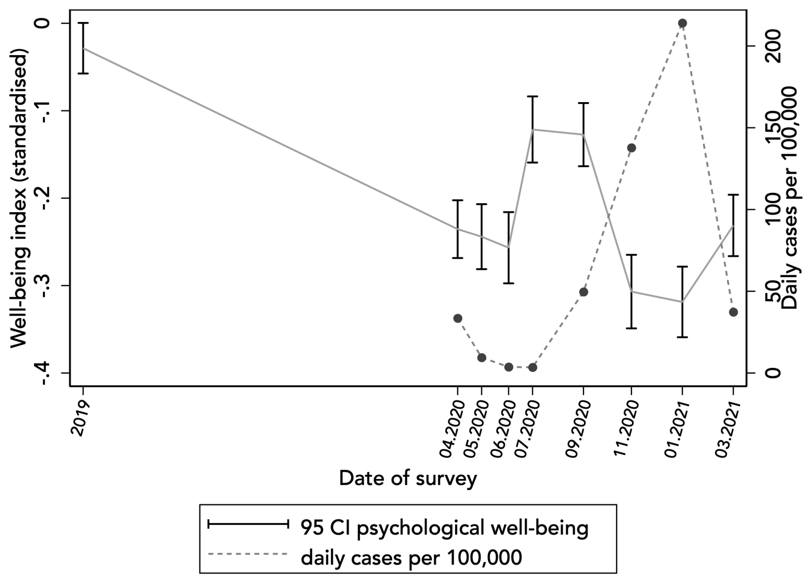


(b) What is the main reason you would not take the vaccine?



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).

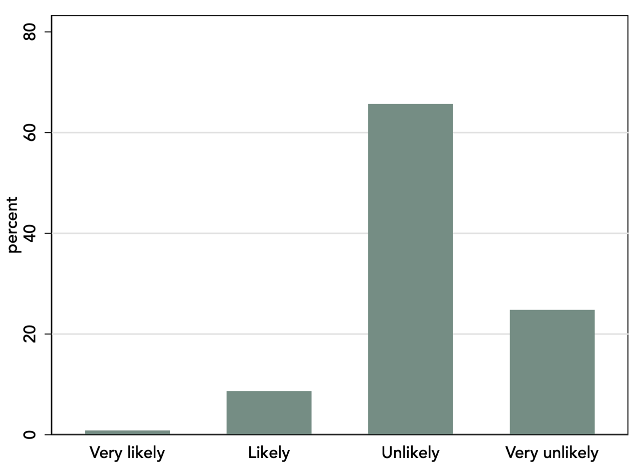
Figure A4: Psychological well-being (GHQ-12) and COVID-19 incidence: 2019-2021.



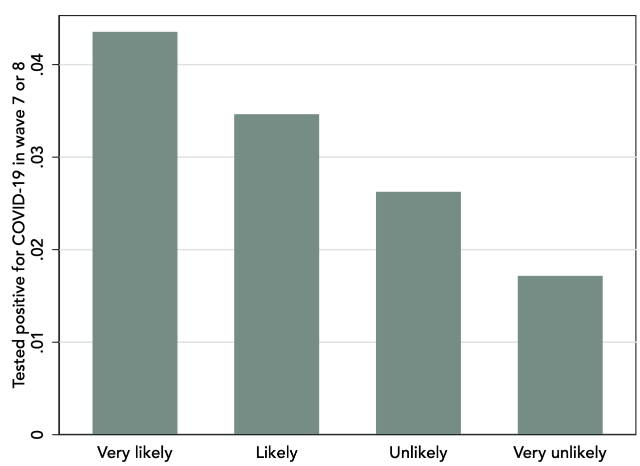
Notes: Population-weighted mean and 95% confidence intervals at survey dates from the main survey and the COVID-19 survey of *Understanding Society*. Information on daily cases from Public Health England.

Figure A5: COVID-19 risk assessment and subsequent probability of testing positive

(a) Perceived COVID-19 risk

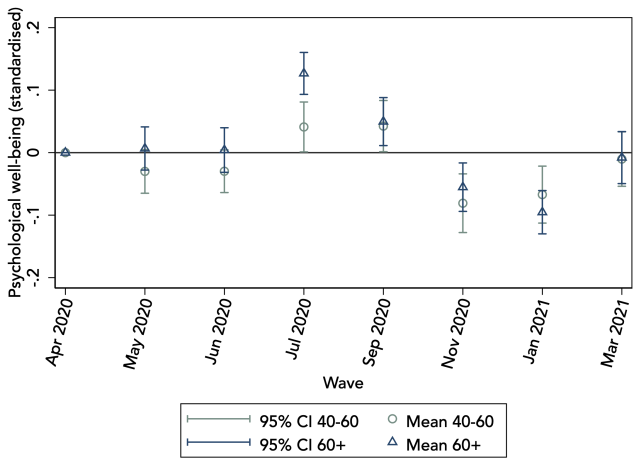


(b) Testing positive by perceived COVID-19 risk



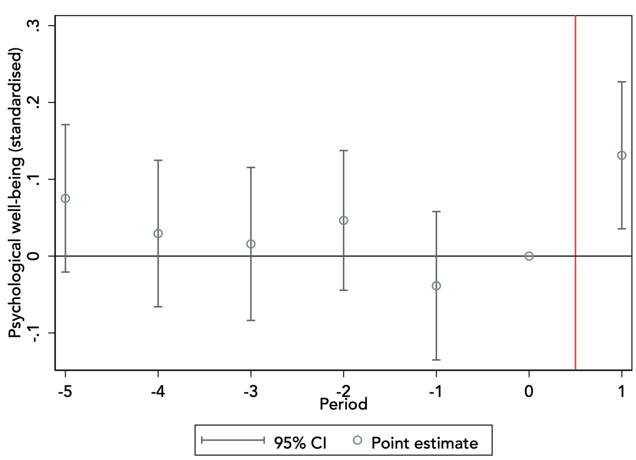
Notes: Population-weighted sample in the COVID-19 survey of *Understanding Society*. In panel (a), perceived COVID-19 risk is measured in wave 6 (November 2020) based on the following question: "In your view, how likely is it that you will contract COVID-19 in the next month?". In panel (b), we show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

Figure A6: Evolution of well-being for different age groups.



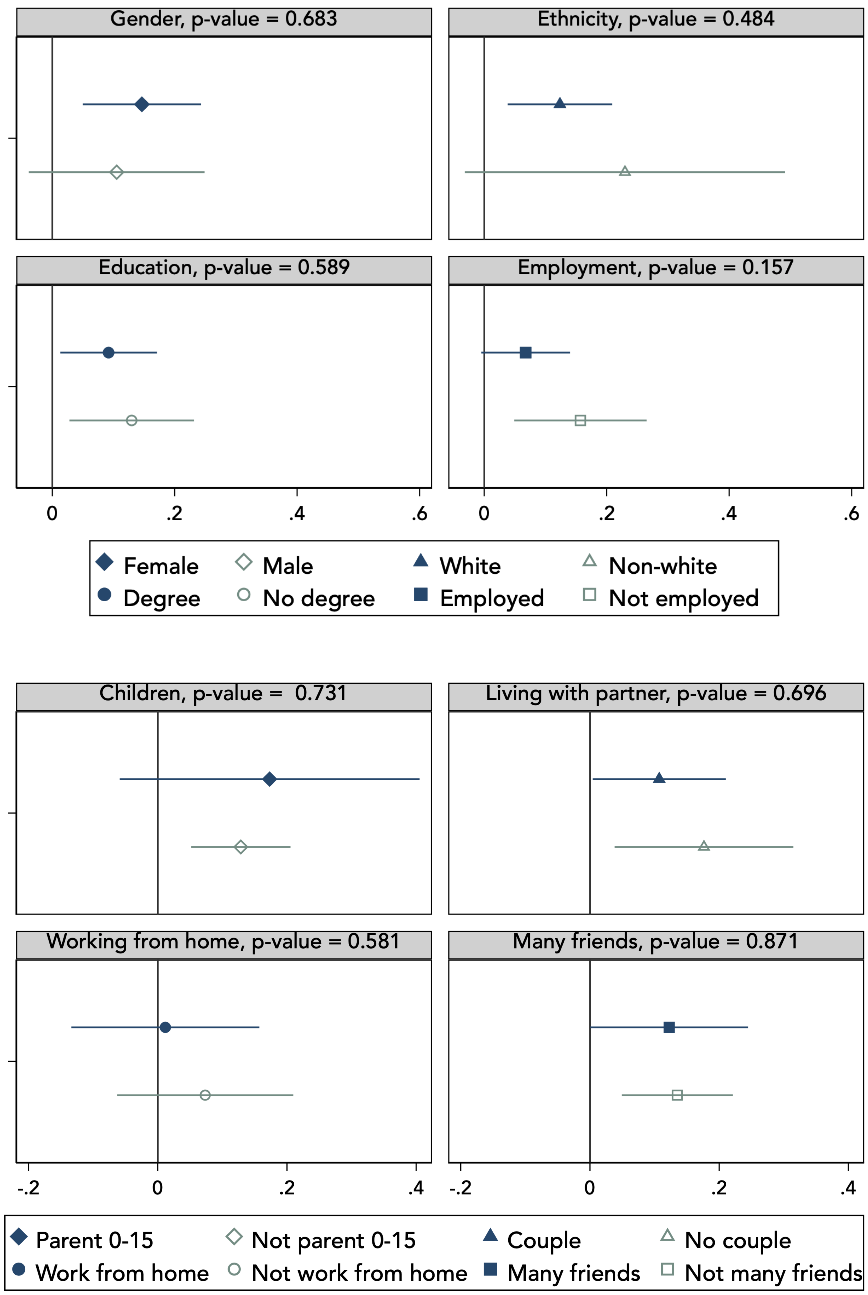
Notes: Authors' calculation, using a OLS regression with individual fixed effects. The omitted group is the April 2020 survey wave and individuals under 40.

Figure A7: Event study - Impact of invitation for vaccination on psychological well-being



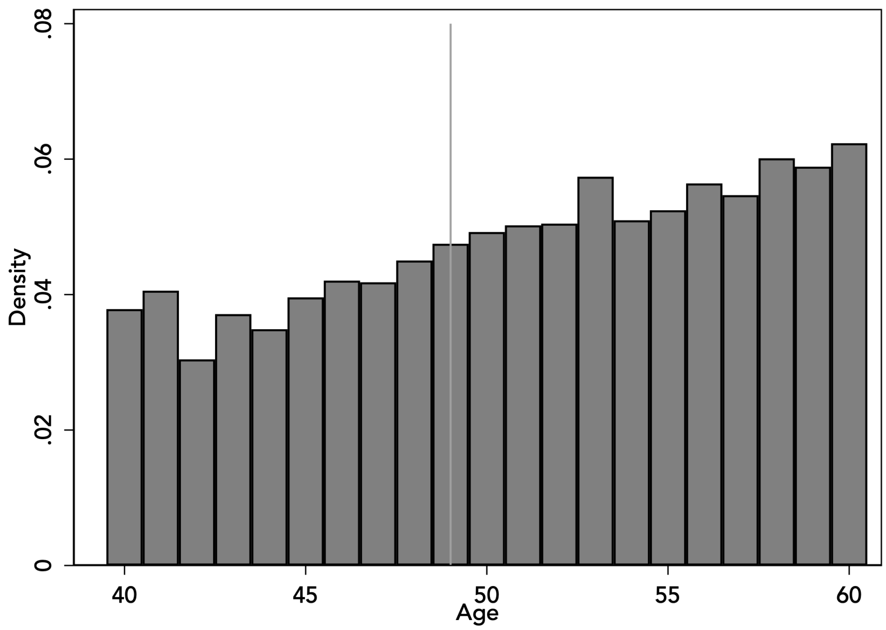
Notes: The figure reports the estimates from the event study analysis of the IV-DID using equation (3). The outcome variable is the standardized and inverted GHQ-12 mean score. The treatment group includes individuals aged 61-80 who had been invited for vaccination by the time of the January 2021 survey 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 A8: 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.

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).