

A Service of



Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Epstein, Gil S.; Heizler, Odelia; Israeli, Osnat

Working Paper Herding and the intention to vaccinate against COVID-19

GLO Discussion Paper, No. 1578

Provided in Cooperation with: Global Labor Organization (GLO)

Suggested Citation: Epstein, Gil S.; Heizler, Odelia; Israeli, Osnat (2025) : Herding and the intention to vaccinate against COVID-19, GLO Discussion Paper, No. 1578, Global Labor Organization (GLO), Essen

This Version is available at: https://hdl.handle.net/10419/313421

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



WWW.ECONSTOR.EU

Herding and the intention to vaccinate against COVID-19

Gil S. Epstein^a, Odelia Heizler^b, Osnat Israeli^c

^a Department of Economics, Bar-Ilan University, Ramat Gan, 5290002, Israel, GLO (Global Labor

Organization) and Institute of the Study of Labor (IZA)

E-mail: Gil.Epstein@biu.ac.il

^b Department of Economics and Management, Tel-Aviv-Yaffo Academic College, Rabenu Yeruham St., P.O.B

8401 Yaffo, 6818211, Israel, GLO (Global Labor Organization) and Institute of the Study of Labor (IZA)

E-mail: <u>odeliahe@mta.ac.il</u>

^c Department of Economics, Ashkelon Academic College, Ben Tzvi 12, Ashkelon 78211, Israel, and GLO (Global Labor Organization)

E-mail: asntisra@edu.aac.ac.il

Abstract

This paper investigates the effect of herd behavior, or information cascades, on the willingness to be vaccinated against COVID-19. We use the 2021/2022 wave of the European Social Survey combined with data from the organization Our World in Data and measure the herding behavior as the change in the share of vaccinated people in the population just prior to the individual's decision. Controlling for sociodemographic characteristics, health status, COVID-19 illness history, and pandemic-related features, the results show that the information cascade significantly increases vaccination intentions. This suggests that the decision on whether to vaccinate is affected by the behavior of others. Moreover, we find a U-shaped association between the herd effect and the share of the population that is vaccinated. Finally, the herd effect on the vaccination decisions of young people, people in poor health, and immigrants is higher than for others.

Keywords Herd Behavior, COVID-19, Vaccination, European Social Survey, Information

Cascades

JEL codes I12, D91

1 Introduction

Is it worth buying a certain brand? Should I emigrate to another country? These are examples of simple, albeit difficult decisions that an individual must make where the benefits and costs of those decisions are not perfectly known. In such cases, individuals sometimes tend to rely on the behavior of others, even when they do not know what the basis of the others' decision is, i.e., whether they are acting on their own signal or are also following others. This phenomenon is known as herd behavior (Banerjee 1992; Bikhchandani et al. 1992), and has implications for a wide variety of economic circumstances (for examples, see Bauer et al. 2002; Demirer et al. 2010; Kennedy 2002; Scharfstein and Stein 1990). Less investigated is herd behavior in the context of deciding whether to vaccinate against COVID-19.

The decision of whether to get vaccinated is not an easy one, as the costs and benefits, e.g., the risk of side effects, the risk of getting the disease, and the benefit to others, are sometimes hard to assess. When considering a novel vaccine such as that for COVID-19, the lack of information is even more salient. There is a wide range of literature investigating the willingness to vaccinate in general, and to get the COVID-19 vaccination in particular (e.g., Dubé et al. 2013; Giulietti et al. 2023; Grüner and Krüger 2021). We theorize that in addition to the traditional sociodemographic and psychological factors influencing this decision, individuals also look at the decisions made by others when making their own, i.e., they follow the herd.

In this study, we investigate the effect of herd behavior, or following information cascades, on the willingness to vaccinate, where herding is measured as the change in the share of the vaccinated population in the week preceding the respondent's interview, following Bauer et al. (2002). The results show that individuals are indeed affected by the behavior of others when considering whether to get vaccinated, with the herd significantly increasing the

willingness to vaccinate. We also find that there is a U-shaped association between the herd effect on vaccination intentions and the share of vaccinated individuals. The results are strengthened by several robustness checks, in which we consider alternative durations of time for the herd variable, shift its measurement to the change in the share of vaccinated individuals 2 and 3 weeks prior to the decision, consider various levels of the share of the vaccinated population, and limit the investigated period.

The willingness to vaccinate has been extensively investigated in the literature; however, to the best of our knowledge, only very few studies have empirically examined the herd effect on vaccination behavior (see Agranov et al. 2021; Cohen et al. 2013; Kairiza et al. 2023). The two former studies considered the willingness to vaccinate as a function of hypothetical assumptions concerning the behavior of others, and not their actual vaccination uptake, whereas the latter study was limited to rural Zimbabwe. The present study contributes to the literature on vaccination in general, and on the association between herding behavior and vaccination decisions in particular, in three ways. First, our data were collected when vaccinations were already available, whereas in Cohen et al. (2013) and Agranov et al. (2021), individuals were required to imagine that a vaccine against COVID-19 was available for anyone who wanted it, as well as to assume what the other individuals' behavior would be. Making a decision when the vaccine is actually available, and when one sees that others, and how many others, are getting the vaccine may yield different results than when the decision is based on hypothetical assumptions. Second, this study is based on rich data from 20 countries, whereas other studies were based on one country or on a limited sample. Our data enabled us to examine the varied effects of herd behavior on different groups. Third, our data were collected over a year and a half—a relatively long period, thus covering a wide range of shares of vaccinated individuals in a population, and enabling us to explore the impact of the information cascade at different levels of vaccination.

The paper is organized as follows: in section 2, we review the literature on herd behavior/information cascades and vaccination; in section 3, we introduce the datasets deployed in this research, the estimation procedure, and the specifications used; section 4 presents the results, section 5 several robustness checks, and section 6 concludes.

2 Literature review and background

2.1 Herd behavior

Herd behavior is a well-known phenomenon in economics. In 1936, Keynes explained investors' actions as "following the herd," and a theoretical rationalization for this was provided in the seminal works of Banerjee (1992) and Bikhchandani et al. (1992). Herding occurs when an individual who faces a decision for which he or she has incomplete information tends to imitate the actions of others, believing that they have important information that he or she does not have. The individual does not know what the basis of the others' decision is, i.e., whether they are acting on their own signal or are also following the herd; nevertheless, it has been shown that under certain conditions, an individual's decision to follow information cascades, even when this goes against his or her own signal, may be an efficient decision (Epstein 2008).

The economic literature has also examined the question of who creates the herd. Gul and Lundholm (1995) presented a model in which agents chose when to make a decision, given the existence of a trade-off between rapid and more accurate decisions. They showed that this situation created a tendency for clustered decisions even when there was no information cascade. Banerjee (1992) noted that if the order in which individuals made their decisions was endogenous and the waiting cost was low enough, agents with signals would make their decisions before agents without signals.¹

Herding is mostly depicted in the financial market, and is often blamed for stock market bubbles and crashes, when individual investors follow the others in a rush to get in or out of the market (e.g., Bekiros et al. 2017; Demirer et al. 2010; Scharfstein and Stein 1990). Economic literature also finds herding in immigration decisions; Epstein (2008) developed a theoretical model showing that, along with network externalities, herd behavior explains why emigrants from the same location make the same foreign relocation decision, believing that the prior emigrants had information that they do not have, even if they would have independently chosen to go elsewhere. Bauer et al. (2002) empirically implemented the theory for Mexican immigrants in the United States, and Epstein and Heizler (2006) did so for Former Soviet Union immigrants in Israel. Herding also has implications for a variety of other decisions. Epstein and Gang (2024) presented a model of optimal taxation in an environment of high corruption. They showed that herding affects the optimal resources invested by interest groups (the poor and the rich) who act strategically to drive policy for their own benefit. Kennedy (2002) found that broadcast television networks imitate each other when introducing new programs, but that this leads to lower ratings and shorter average runs for those programs as compared to programs that are different. Consumption decisions were found to be based on the information received by individuals from their peers when product quality was difficult to observe in advance (Moretti 2011; Sorensen 2006). Health decisions may be similarly affected; Bennett et al. (2015) suggested that people who feared the high infection rates in hospitals during the SARS

¹ In the context of the Covid pandemic, the herd was created exogenously. Health authorities gave priority to vaccinating those whose waiting costs were higher, e.g., health workers and the elderly (Wiśniowska et al. 2022). The individuals who were vaccinated after them were actually "hitchhikers," using the experience created by the vaccination of these groups. Later on, the age for receiving the vaccine was lowered and the restrictions were removed.

epidemic in Taiwan were responding to public information, but also to the behavior and opinion of their peers, when avoiding the health care system.

However, only a few papers have examined the effect of information cascades on vaccination behavior empirically, most of them considering the willingness to vaccinate as a function of hypothetical assumptions concerning others' behavior, rather than actual vaccination uptake. Cohen et al. (2013) hypothesized that during the 2009 swine flu pandemic, individuals would mimic their peers because they had insufficient information about the benefits and risks of the vaccine. Those authors asked 95 undergraduate medical students to provide subjective estimates of the risks and benefits of the disease and vaccination; these were used to generate a population utility model. The participants were also asked about their intention to vaccinate when considering four different vaccination rates among their peers. Their results showed that about 60% intended or did not intend to vaccinate irrespective of their peers' decisions. Among the other 40% of the participants, the decision to vaccinate was positively associated with the presumed peer vaccination rate, indicating possible herd behavior.

The importance of taking into account insights from behavioral economics in explaining irrational behavior during the COVID-19 pandemic, such as herding behavior, among other phenomena, has been stressed by Soofi et al. (2020) and, as far as we know, two papers have done so. Agranov et al. (2021) investigated the role of herding, social norms (feeling compelled to vaccinate if everyone else does), and free-riding on the intention to vaccinate. The 1,500 participants were asked whether they plan to vaccinate if the COVID-19 vaccine is approved by the Food and Drug Administration and becomes available. They were also asked about their beliefs regarding how many other respondents would declare their intention to vaccinate; the correlation between these two questions might suggest herd behavior as well as following social norms. Two other questions were presented to the participants:

would they plan to get vaccinated if experts said that they would get vaccinated themselves, and what were their beliefs about the effects of the above information on the behavior of others? The effect of the additional information embedded in experts' opinion on the intention to vaccinate should indicate the role played by herding on this intention. The results indicated that free-riding is not a dominant effect, whereas the people's responses to information on experts' propensity to vaccinate suggested that herding also plays a limited role, and that social norms are probably the dominant effect. They also found that gender and political preferences play a role in the decision to get vaccinated.

Kairiza et al. (2023) looked at the impact of herding behavior on the opposite of intention to vaccinate—vaccine hesitancy. They estimated the probability of a household in rural Zimbabwe not planning to vaccinate against COVID-19 as a function of its distance from other households that did not intend to get the vaccine, as well as socioeconomic characteristics, risk perceptions, and information available from social workers. They found that the larger the number of vaccine-hesitant households near a particular household, the more likely that the latter household would hesitate to get vaccinated, indicating herding behavior.

2.2 The willingness to vaccinate

The present study is related to the literature on the determinants of vaccination uptake. A vast epidemiological literature, and to a lesser extent economic papers, have considered different factors affecting an individual's willingness or reluctance to get vaccinated in general, and to get the COVID-19 vaccine in particular. The decision to get vaccinated is a rational choice between the risk of contracting the disease and the risk of experiencing vaccine side effects, which may be prone to biases (Böhm et al. 2016) and misinformation (Carrieri et al. 2019; Dubé et al. 2013). Moreover, the perceptions of the risks involved in the decision are affected by demographic, structural, social, and behavioral factors (for a thorough overview of psychosocial factors affecting vaccine acceptance, see Dubé et al. 2013). For example, Huang et al. (2023) examined the causal relationship between vaccination and individuals' risky behavior using data from China. They found that exposure to the anti-HBV vaccine reduces the likelihood of regular alcohol drinking among men. Government intervention policies also play a role in achieving the optimal level of vaccination (Brito et al. 1991).

The COVID-19 pandemic has notably led to a still-growing body of work on the determinants of the willingness to get this specific vaccine, focusing on a wide variety of factors, briefly reviewed here. In addition to sociodemographic determinants and the respondents' health status, some papers considered the role of different aspects of trust (Grüner and Krüger 2021), with mixed results. The importance of vaccine properties, for example, its site of delivery and its expected efficiency, has also been investigated (McPhedran and Toombs 2021; Pelegrin-Borondo et al. 2021). Lepinteur et al. (2023) investigated the ambiguous effect of risk aversion, as it affects both the perception of vaccination costs—the probability of side effects, and the perception of its benefits-the probability of reducing the risk of death or severe disease; they found a stronger effect of the latter. Giulietti et al. (2023) investigated how information about disease severity, as implied by the death rate in a particular locality, affects the vaccination ratio at the local level and the intention to vaccinate at the individual level; they found that vaccination ratio in the locality increased with COVID-19-related deaths, with a stronger effect in localities with a larger ethnic minority population. They did not find evidence of an effect on the intention to vaccinate; however, they did show that although ethnic minorities had a lower intention to vaccinate than the majority, their intention increased more rapidly with the number of local COVID-19 deaths, theorizing that information moves more rapidly in the more tightly connected ethnic communities. Angerer et al. (2023) examined how

the process of a vaccine's approval affects public attitudes toward vaccination using data from Germany. They found a positive relationship between the duration of the approval process and intention to vaccinate only when Emergency Use Authorization was involved.

Some countries have implemented incentive programs to encourage individuals to get vaccinated. Robertson et al. (2021) and Barber and West (2022) investigated the impact of lottery schemes in the United States, where individuals who were vaccinated had a chance to win large sums of money. Robertson et al. (2021), who studied the programs' effects shortly after they were implemented, found that they had a positive, statistically significant, and economically meaningful impact on vaccine uptake in most investigated states. Barber and West (2022) estimates showed that Ohio's incentive scheme increased the share of vaccinated individuals in the state population, and claimed that the social benefit of the program was larger than its cost.

2.3 Evolution of COVID-19 and anti-COVID vaccination in Europe

The extensive and still-emerging research on COVID-19 can be attributed to the severe nature of the pandemic. First detected in China in December 2019, the rapidly spreading COVID-19 virus was declared a Public Health Emergency of International Concern by the World Health Organization on 30 January 2020 and was characterized as a pandemic on 11 March 2020. The first COVID-19 cases in Europe were recorded in France on 25 January 2020 (World Health Organization 2020) and since then, over 2 million people in the European Region have died of the disease.² The pandemic's evolution in Europe consisted of roughly three main COVID-19 waves from the start of the pandemic till the end of 2022 (defined by daily deaths; Easterlin and O'Connor 2023). The number of deaths in the first wave was considerably lower than in

² <u>https://www.who.int/europe/emergencies/situations/covid-19.</u>

the next two waves, and even though the third wave exhibited a record-high number of cases due to the highly contagious Omicron variant, its lower fatality let to a decline in new COVID-19 deaths in the third wave compared to the second (Easterlin and O'Connor 2023; World Health Organization 2023).

The decline in deaths per case in the third wave could also be due to the development and distribution of COVID-19 vaccines (Easterlin and O'Connor 2023), which were introduced at the end of December 2020. Vaccination programs in most countries prioritized frontline medical workers as well as personnel and residents of nursing homes, and then society's senior members (Wiśniowska et al. 2022), widening the availability in the second phase of vaccination. By June 2021, most European countries offered the vaccine to all adults, and by the end of 2021, all European countries were applying a universal access policy.³

To the best of our knowledge, ours is one of the few studies to investigate herd behavior in the context of vaccination, and it is the first study to investigate the impact of information cascades on the willingness to vaccinate by using the real actions of others. We provide evidence, based on large cross-sectional data from 20 countries, that recently vaccinated individuals signal followers, triggering them to do the same.

3 Data and estimation

3.1 Data

The current research makes use of three datasets: the European Social Survey (ESS) dataset; data from the organization Our World in Data (OWID) (Mathieu et al. 2020); and the Oxford

³ <u>https://ourworldindata.org/covid-vaccinations#vaccination-policies</u>.

Covid-19 Government Response Tracker (OxCGRT) (Hale et al. 2021).⁴ The first dataset is the 10th round of the ESS, from which individual data were obtained. The ESS is a biennial crossnational survey that has been conducted across Europe since 2001 and is widely used in socioeconomic research (e.g., Kovacic and Orso 2023). The survey measures the attitudes, beliefs, and behavioral patterns of diverse populations in 40 nations. The ESS samples are representative of all persons aged 15 years and older living in private households in each country, and individuals are selected by strict random probability methods at every stage. The survey involves a high response rate and rigorous translation protocols. The survey began in May 2021 and continued until September 2022, with each country surveyed for about 6 months. In May 2021, less than 8% of the world population and about 22% of the European population were vaccinated. As can be seen in Fig. 1, during the long period of the survey, the vaccination rate rose dramatically, and this allowed us to examine the effect of information cascades on the willingness to vaccinate.



⁴ The ESS data can be downloaded from the ESS website: http://www.europeansocialsurvey.org/data/; OWID from https://ourworldindata.org/; OxCGRT from https://github.com/OxCGRT/covid-policy-tracker.

Fig. 1 Share of vaccinated population by country from May 2021 to August 2022. Source: Authors' process of ESS and OWID data

Until round 10, the ESS data collection had been based on an hour-long face-to-face interview, but due to the COVID-19 pandemic, in this round, 9 countries used a self-completion questionnaire, while 22 countries⁵ used the usual face-to-face approach. As results are difficult to compare when different sampling methods are used, we applied the analysis solely to the face-to-face interviews. Two countries were excluded from the estimation, France and Montenegro, because data on the willingness to vaccinate, the main variable of the research, were missing. In addition, in Slovenia, only some of the observations were included in the analyzed sample; most respondents were interviewed before the vaccinations had become available, and therefore were not included in the analysis.⁶ The second source of data was OWID, which focuses on important issues, such as environment and poverty, as well as the COVID-19 pandemic (Mathieu et al. 2020) from which data were retrieved to construct the herd behavior data. The dataset includes a time series by country on COVID-19 cases, vaccinations, etc. OWID uses the most recent official COVID-19 numbers from governments and health ministries worldwide and is used by many researchers (e.g., Agrawal et al. 2023; Hierro et al. 2023). Data on policy response were retrieved from OxCGRT (Hale et al. 2021), a widely used dataset (e.g., Zamfir and Iordache 2022) that documents government policies related to closure and containment, and health and economic policies, for more than 180 countries.

3.2 Main variables

⁵ The countries are Belgium, Bulgaria, Croatia, Czechia, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Montenegro, North Macedonia, Netherlands, Norway, Portugal, Slovakia, Slovenia, Switzerland, and the United Kingdom.

⁶ The results did not change when omitting Slovenia from the sample.

Our analysis focused on vaccination intentions: "Will you get vaccinated against coronavirus with a vaccine that was approved by the national regulatory authority in [country]?" The answer was coded 1 if the respondent answered "yes, I will" and 0 if the answer was "no". Missing values were assigned to respondents who had received at least one dose of the vaccine.

The main independent variable in the analysis was the herd effect. On the one hand, an individual faces time and effort costs when considering vaccination, and he or she may also fear possible side effects, a fear that could be enhanced by exposure to misinformation spread by anti-vaccination movements. On the other hand, the individual sees the flow of people who have already been vaccinated, assuming that these people have information that he or she does not have and that can influence his or her decision. We explored the effect of information cascade on the individual's decision to get vaccinated based on the method proposed by Bauer et al. (2002), capturing the herd effect by looking at the change in the share of people who were recently vaccinated against COVID-19. Throughout the long period of the survey, the rate of those getting vaccinated changed dramatically, allowing us to examine the effect of the informational cascade on the willingness to vaccinate. The herd effect was therefore calculated as:

$$herd_{ic} = share_{ict} - share_{ic(t-1)}$$
(1)

where $share_{ict}$ is the share of individuals who were vaccinated against COVID-19 as related to individual *i* from country *c* interviewed at time *t*. Similarly, $share_{ic(t-1)}$ is the vaccination rate in the country at time t-1; $herd_{ic}$ is then the change in the share of vaccinated individuals in the country occurring in a particular time interval prior to the individual's interview. In the first stage of the analysis, we considered a time interval of 1 week prior to the respondent's interview. Other time intervals before the respondent's interview are considered in section 5 as robustness checks. We would like to be more cautious and acknowledge that the herd variable may encompass other behavioral effects, such as social pressure or social norms, as described by Agranov et al. (2021). For instance, if more individuals are vaccinated, one may feel more compelled to be vaccinated as well. We considered adding the vaccination rate as an independent variable to proxy for social pressure, although this variable might similarly include herd effects (Agranov et al., 2021). However, the share of vaccinated individuals in a country is highly correlated with the country fixed effects, making it unfeasible to examine. Additionally, this variable may also capture free-riding behavior; a high vaccination rate might lead individuals to assume that herd immunity will be achieved, thereby reducing their motivation to get vaccinated.

3.3 Estimation method

To estimate the effect of herding on the willingness to vaccinate against COVID-19, our specification takes the form:

$$Y_{ic} = \beta_0 + \beta_1 herd_{ic} + X_{ic}\gamma + \varepsilon_{ic}$$
⁽²⁾

where Y_{ic} is a binary variable indicating the intention of individual *i* from country *c* to get vaccinated; *herd*_{ic} is the change in the share of individuals vaccinated in the week leading up to the respondent's interview, as defined above.

The vector of control variables, X_{ic} , includes: age, education, gender, immigrant status, religion, generalized trust, and subjective health status, all of which have been used in previous research (Costa-Font et al. 2023; Giulietti et al. 2023). We also included variables for COVID-19 illness history, and a dummy variable for the Omicron wave or variables related to the added

restrictions on unvaccinated compared to vaccinated individuals interchangeably. The exact definitions of the variables are presented in Appendix A, along with their descriptive statistics.⁷ Country fixed effects were also included, controlling for differences in vaccination intentions resulting from country-specific factors, and $\epsilon_{i,c}$ is the error term.

At the beginning of the ESS, vaccination had already been initiated,⁸ and it continued to expand during the ESS interviews. Thus, most of the respondents were already vaccinated when surveyed. The data do not include the date of vaccination, so we could not examine the herd effect on vaccinated individuals but only on unvaccinated respondents' intention to vaccinate. Consequently, a sample selection problem arises, as the sample is not randomly selected and includes solely individuals who decided not to get the vaccine, at least until the date of their interview. If individuals made this decision randomly, we could ignore the sample selection and use ordinary regression. However, this assumption is unlikely to be valid; respondents who had not been vaccinated at the time of the interview were influenced by various factors, most of which would probably influence their further intention to vaccinate. Hence, ignoring sample selection would plausibly yield biased estimates that do not represent the population. To address this problem, we used a two-step Heckman Probit model with sample selection that provides consistent, asymptotically efficient estimates for all of the parameters in such models.

In the Probit model with sample selection, the first step is to estimate the probability of the individual to be unvaccinated, and equation (2) is estimated in the second step, with estimated coefficients that represent the marginal effects of the covariates on all individuals' intention to vaccinate. Therefore, about 30,650 observations were included in the first-step estimation, of which about 8,240 were not yet vaccinated and were included in the second-step

⁷ The descriptive statistics are weighted using the ESS analysis weights.

⁸ Except for Slovenia, thus only part of the sample was included in the analysis, as elaborated in section 3.1.

estimation. However, to precisely identify the model, we needed at least one variable that affects the probability of being unvaccinated at the time of the survey, but not the intention to vaccinate. Thus, in addition to almost all of the control variables of equation (2), the first-step estimation included a dummy variable receiving the value 1 if the interview was conducted before July 2021, 3 months after the survey began, and 0 otherwise. The assumption was that being interviewed at the beginning of the sample increases the probability of being unvaccinated, since all countries in the sample deployed vaccine prioritization programs until around the middle of 2021 (except for North Macedonia for which data on prioritization were not available), but should not affect the probability of the intention to get vaccinated. The results of the first-step estimation are presented in Appendix B.

In addition, there is likely to be heterogeneity in the impact of the information cascade related to the different shares of vaccinated individuals in the population; plausibly, as the share of vaccinated individuals rises, the information available to those who are not yet vaccinated increases, and they will be less obligated to rely on the behavior of others. Hence, we further estimated an augmented specification, which includes an interaction between the herd variable and dummy variables for different rates of vaccination:

$$Y_{ic} = \beta_0 + \beta_1 herd_{ic} + \beta_2 herd_{ic} \cdot Med \ Share_{ic} + \beta_3 herd_{ic} \cdot High \ Share_{ic} + X_{ic}\gamma + \varepsilon_{ic} \quad (3)$$

where *Med_Share_{ic}* is a dummy variable receiving the value 1 if the share of the vaccinated population in country *c* when individual *i* is interviewed is between 40 and 70%, 0 otherwise, and *High_Share_{ic}* indicates that the share of the vaccinated population is over 70%, respectively. The main parameters of interest are β_2 and β_3 , which tell us whether respondents are affected differently by herding when vaccination share varies. We expect that as the share of vaccinated individuals increases, the influence of the signal received by the herd will diminish, resulting in a decreasing effect of the herd.

The herd effect could also vary with individuals' characteristics, for example, if the individual is an immigrant. As shown by Giulietti et al. (2023), immigrants may have different social networks than natives, and may therefore be affected differently by the information cascade. To investigate this potential heterogeneity, we use the following specification:

$$Y_{i,c} = \beta_0 + \beta_1 herd_{i,c} + \beta_2 immigrant_{i,c} + \beta_3 herd_{i,c} \cdot immigrant_{i,c} + X_{i,c}\gamma + \epsilon_{i,c}$$
(4)

where β_3 indicates whether an immigrant reacts differently to the information cascade than natives.

Another source of heterogeneity in the herd effect could be the age of the respondents as young individuals may be differently affected by the herd if they are, for example, more exposed to varied media sources or, as immigrants, have different social networks than older individuals.⁹ They are also less prone to severe disease, which may also affect their impact from informational cascades. Thus an interaction of the herd variable with a dummy variable for young respondents was also explored. Heterogeneity of the herd impact by education, and health status was similarly tested.

All estimations applied standard errors clustered at the country level and observations were weighted using the ESS analysis weights, correcting for differential selection probabilities within each country as specified by sample design for non-response, non-coverage, and sampling error related to the four post-stratification variables, and taking into account differences in population size across countries.

⁹ Young individuals' intention to vaccinate may be quite different than older ones, not only in the context of herd effect but also, for example, in their reaction to restriction policies or the effect of previous illness. Concentrating more closely on different age groups was not in the scope of this paper and may be explored in further research.

4 Results

The estimations of the second step of the Heckman Probit selection model in which the outcome of interest is the willingness to vaccinate (equation 2) are presented in Table 1. The specification in the first column includes sociodemographic variables, a general trust variable, and country fixed effects.¹⁰ We then introduce other control variables to ultimately produce two alternative full models in columns (4) and (5).¹¹

 Table 1 Herd behavior and the willingness to vaccinate: a second-step estimation of a Probit

 model with sample selection

	1	2	3	4	5
Herd	0.128***	0.136***	0.122***	0.124***	0.123***
	(0.030)	(0.029)	(0.026)	(0.027)	(0.034)
Controls:					
Sociodemographic	V	V	V	V	V
Trust	V	V	V	V	V
Subjective health status		V	V	V	V
COVID-19 illness			V	V	V
history					
Omicron dummy				V	

¹⁰ The full specifications are presented in Appendix C.

¹¹ The specification of the first-step regression of the Heckman Probit procedure is the same for all specifications in Table 1. The results are generally the same and we present the first step of specification (1) only, in Appendix B, to avoid repetition.

Stringency difference					V
Country fixed effects	V	V	V	V	V
Observations	8,377	8,371	8,239	8,239	7,857
Log pseudolikelihood	-10,283.1	-10,257.5	-10,135.7	-10,133.0	-9,998.0

Notes: Sociodemographic controls include age, education, gender, religiosity level, and a dummy variable for a first-generation immigrant. Standard errors are in parentheses and are clustered at the country level. ***Significant at 1% level.

The first result that emerges in all specifications is that there exists a positive and statistically significant relationship between the herd variable and the willingness to vaccinate, suggesting that the larger the change in the share of vaccinated individuals in the country, the higher the probability of an individual having a positive intention to get the vaccine.

Columns (2) through (5) of Table 1 add the various control variables in equation (2) in turn. In column (2), subjective (as defined by the interviewee) health status is added, as it affects cost and benefit perceptions and thus the intention to vaccinate. Similarly, column (3) adds two dummy variables indicating that the individual tested positive for COVID-19 or thinks that he or she had COVID-19 (but was not tested). Column (4) controls for the evolution of the pandemic with a dummy variable for January and February 2022, when the number of COVID-19 cases rose dramatically due to the Omicron variant. This variable is added to verify that the herd effect is not dependent on fluctuations in the course of the pandemic.¹² The coefficient of this variable was negative and significant (see Appendix C), indicating that the willingness to vaccinate decreased during this period, presumably because this variant, although highly contagious, was less fatal or because many vaccinated people were also infected.

¹² Other variables were also considered as controls for pandemic features: a dummy variable for the Delta variant, number of hospitalizations at the time of the interview, number of deaths, and the reproduction rate; however, their effect was negligible and therefore they were not included in the estimation; the herd coefficient remained significant in those specifications as well. Results may be obtained from the authors upon request.

Another control variable considered is the stringency index, retrieved from OxCGRT (Hale et al. 2021). This index averages nine metrics, each ranging from 0 to 100 (with 100 being the strictest): school closures, workplace closures, cancellation of public events, restrictions on public gatherings, closures of public transport, stay-at-home requirements, public information campaigns, restrictions on internal movements, and international travel controls. This variable was not significant when included in the regression, thus the last specification includes the difference between the stringency index for non-vaccinated individuals vs. vaccinated ones, assuming that additional restrictions on unvaccinated individuals would affect the benefits from vaccination and encourage individuals to vaccinate.¹³ This variable was not statistically significant as well when introduced into the regression as is, possibly because the difference was zero or low in more than a third of the observations. However, a positive and significant effect (at the 10% level), indicating higher intentions to vaccinate when the difference in restrictions was higher,¹⁴ was found for the interaction between this variable and the dummy variable for the year 2021, perhaps because the stringency index and the difference between the stringency index for vaccinated and unvaccinated people decreased dramatically in 2022, causing the restrictions to be less relevant in that year. The estimated herd coefficient is remarkably stable across the different specifications; as such, the relationship between herding behavior and vaccination intentions is not altered by the wide variety of control variables introduced.

Our next step was to investigate whether the herd effect varies for different vaccination shares, as depicted by equation (3). The results are presented in Table 2.

¹³ North Macedonia is not included in this specification as this country has no records in the OxCGRT dataset, from which the stringency index was retrieved.

¹⁴ See Appendix C.

Table 2 Herd behavior and the willingness to vaccinate: heterogeneous effect for different shares of vaccinated individuals; a second-step estimation of a Probit model with sample selection

	1	2	3	4	5
Herd	0.134***	0.144***	0.134***	0.129***	0.137***
	(0.029)	(0.030)	(0.027)	(0.025)	(0.035)
Herd*medium share 40–	-0.043**	-0.045**	-0.046**	-0.049***	-0.052***
70%	(0.021)	(0.022)	(0.020)	(0.018)	(0.018)
Herd*high share >70%	0.041	0.035	0.013	0.057	0.011
	(0.040)	(0.043)	(0.067)	(0.058)	(0.063)
Controls:					
Sociodemographic	V	V	V	V	V
Trust	V	V	V	V	V
Subjective health status		V	V	V	V
COVID-19 illness			V	V	V
history					
Omicron dummy				V	
Stringency difference					V
Country fixed effects	V	V	V	V	V
Observations	8,377	8,371	8,239	8,239	7,857
Log pseudolikelihood	-10,282.1	-10,256.7	-10,135.0	-10,131.8	-9,997.2

Notes: Sociodemographic controls include age, education, gender, and religiosity level, and a dummy variable for a first-generation immigrant. Standard errors are in parentheses and are clustered at the country level. ***.**Significant at the 1% and 5% level, respectively.

It is easy to see from Table 2 that the herd variable does not show a monotonously decreasing effect as the share of vaccinated individuals increases as assumed, but there is a U-shaped association between the herd effect and the share of vaccinated individuals. In the beginning, the information cascade significantly increases the willingness to get vaccinated. As the share of vaccinated people increases, the positive effect is still significant, as post-estimation tests showed. Still, it is significantly reduced, possibly because the individual is getting used to seeing vaccinated people around him or her, so it is less effective, as we expected. However, when the share of the vaccinated population is high enough, the effect of the herd increases back to its original level, perhaps because of a stronger, offsetting impact of social norms—people feel obliged to vaccinate when almost everyone is vaccinated. It is less likely that the herd variable solely reflects social norms, as in that case, we would have expected a monotonous increasing effect.

Fig. 2 presents the U-shaped relation between the share of vaccination and the impact of the herd depicted in Table 2 column (4), along with results obtained from regressions applying different cut-off points of the share of the vaccinated population which are further discussed in section 5.



Fig. 2 Herd effect at different shares of the vaccinated population. The estimation points are in the middle of each range. The graph in bold depicts the herd effects calculated from the results in Table 2 column (4). All estimations include the following controls: age, education, gender, religiosity level, a dummy variable for a first-generation immigrant, trust, subjective health status, COVID-19 illness history, Omicron dummy, and country fixed-effects.

In Table 3, we turn to an investigation of whether the effect of the information cascade varies with individuals' characteristics.

 Table 3 Herd behavior and the willingness to vaccinate: heterogeneity by individual characteristics; a second-step estimation of a Probit model with sample selection

	1	2	3	4
Herd	0.115***	0.113***	0.128***	0.104***
	(0.030)	(0.029)	(0.031)	(0.025)
Herd*immigrant	0.052*			
	(0.030)			
Herd*bad health		0.153*		
		(0.087)		
Herd*very good health		-0.002		
		(0.029)		
Herd*more than 15 years			-0.022	
of schooling			(0.045)	
Herd*25 years of age or				0.147**
younger				(0.058)

Observations	8,239	8,239	8,239	8,239			
Log pseudolikelihood	-10,132.6	-10,131.6	-10,132.9	-10,129.4			
Notes: All estimations include the following controls: age, education, gender, religiosity level,							
a dummy variable for a first-generation immigrant, trust, subjective health status, COVID-19							
illness history, Omicron dummy, and country fixed effects. Standard errors are in parentheses							
and are clustered at the country level. ***.**.*Significant at the 1%, 5%, and 10% level,							
respectively.							

The results show heterogeneity in the herd effect. Immigrants are more hesitant toward vaccination (see full results in Appendix A), but they seem to be more responsive to the signal received by the information cascade than the natives (column 1 in Table 3). A somewhat similar result was obtained by Giulietti et al. (2023), who found that immigrants were more affected by the death rate in their locality than the natives. They suggested that ethnic communities have stronger social connections so when a community member dies, the news spreads quickly and strongly affects other community members. This explanation could be implemented here as well. If immigrants are more aware of the number of recently vaccinated individuals in their community due to stronger social networks, then they may be more affected by this signal.

Column 2 suggests that individuals who are in (subjective) bad health are also more affected by the information cascade, relative to individuals with perceived fair to very good health.¹⁵ A possible explanation is that people who perceive that they are in bad health, although obtaining more benefits from the vaccine as they are at higher risk for severe disease, could have higher costs due to side effects from the vaccine, thus the signal of the herd is more important for them.

¹⁵ A post-estimation test showed that the two interaction terms were significantly different at the 10% percent level.

We did not find any evidence of a different herd effect on more highly educated individuals (column 3), but it seems that younger individuals, though in general having lower intention to vaccinate (as may be seen from the significant and positive coefficient of the age variable in Appendix C) plausibly as they are less likely to have a severe disease, are more affected by the information cascade than older ones (column 4). This could be because young people have stronger social connections or more access to a variety of media reports.

5 Robustness checks

Four robustness checks are provided to strengthen our results. First, we tried several definitions for the herd variable, to confirm that our results are not arbitrary. We again present the original herd variable, defined as the change in the share of vaccinated individuals in the country in the week prior to the individual's interview for comparison, and then we consider the change occurring in the time interval of 2 weeks, 3 weeks, and 1 month prior to the individual's interview. For these estimations, we use the specification from Table 1 column 4. The results are presented in Table D1 in Appendix D and show that the herd coefficient is significant under all definitions, strengthening the results. Notice that as the time interval of the herd variable lengthens, the change in the share of vaccinated individuals increases, thus the coefficient of the herd declines.

As it appears that information received at any of the examined lengths of time before the interview plays a role in the individual's decision to vaccinate, in the next step we inspected whether there is a difference between the impact of the signal when it is given closer to, or further from the time of the decision. Thus, in addition to the effect of the change in the share of vaccinated people occurring during the week before the respondent's interview, we present the change occurring during the second or third week preceding the interview; in other words, we define the herd as a weekly change in the share of vaccinations, when this week is shifted from the interview date.¹⁶ The results are presented in Fig. D1 in Appendix D¹⁷ and indicate that the signal obtained from the herd is somewhat more important when it is received closer to the interview day, perhaps because it is more present in the individual's memory. This supports the decision to use the change in the share of vaccinations in the week leading up to the interview as the herd variable, even though results were similar when defining the herd as the change occurring during longer time intervals (Table D1 in Appendix D).

Another robustness check concerns the variation of the impact of the information cascade with the share of vaccinations. In Table 2, we detected a U-shaped association between the herd effect and the share of vaccinated people. In Fig. 2, we present specification (4) from Table 2, but with other cut-off points to validate the findings, the detailed estimation results are presented in Table D2 in Appendix D. The results, combined with those in Table 2, clarify the finding that the relationship between the herd effect and the intention to vaccinate is dependent on the share of vaccinated people in the population following a U-shape association. It seems that the herd effect is higher when the share of vaccinations is up to about 40%, then it is lower for shares up to about 70%, then increases again for higher shares.¹⁸

In the last robustness check, we estimated the herd effect for a sample limited to observations obtained in 2021 only. On the one hand, the number of observations is reduced,

¹⁶ We used a separate regression for each definition of the herd because the change in the share of vaccinated individuals in the consecutive weeks is highly correlated.

¹⁷ The first column in the graph describes the herd effect as originally defined in equation (1), obtained from the estimation presented in Table 1 column (4). The herd coefficients presented in the next two columns are estimated using the same specification.

¹⁸ Post-estimation tests showed that the difference between the medium share interaction with the herd and the high share interaction with the herd is statistically significant in almost all of the specifications presented in Table D2.

but on the other, the herd effect should be more pronounced when the signal is received closer to the beginning of the vaccination process, when there is not much information on the vaccines. The results are presented in Table D3 in Appendix D and show that the herd effect is highly significant in the limited sample as well.¹⁹ The coefficient of the herd is lower than in the regression that includes both years, which may follow from the fact that the average value of the herd variable in 2021 is substantially higher than that in 2022.

6 Discussion

This paper contributes to the emerging literature on the willingness to be vaccinated against COVID-19 (for example, Angerer et al. 2023; Giulietti et al. 2023) by focusing on the role of herd behavior, using data from the ESS and OWID for 20 European countries. The key finding is that the information cascade has a significant positive effect on vaccination intentions, meaning that the change in the share of vaccinated individuals in the population in the period preceding the individual's vaccination decision significantly affects that decision. Moreover, the herd effect is non-linear, but there is a U-shaped effect in relation to the share of the vaccinated population. As the herd variable may also reflect social pressure, a cautious interpretation of this finding could be that the herd is more salient when the share of vaccination is low, and when it increases, social norms play a greater role. We also examine several possibilities for the time interval of the herd, finding that they all significantly affect the individual's behavior. The results, however, can also have negative implications. For example,

¹⁹ Another specification was also estimated for the limited sample, including the interactions of the herd variable with different levels of the share of vaccination. The results were similar to those in Table 2 and thus omitted to avoid repetition.

if the individual recognizes an increase in vaccination hesitancy in the period preceding his or her decision, the information cascade can decrease his or her willingness to get vaccinated.

This study has two main limitations. First, our sample collections began in May 2021, while the COVID-19 vaccines in the surveyed countries became available in December 2020 or in January 2021. Therefore, the data do not allow us to explore the formation and development of the information cascade from the beginning. Second, the late starting point of the survey, combined with the fact that as the survey continued the vaccination rate increased,²⁰ resulted in about 80% of the survey's respondents being vaccinated at the time of their interview. The ESS data do not report the date of vaccination for vaccinated respondents, which is essential to identifying the herd; thus, the investigated sample of unvaccinated respondents was relatively small, and although we used a two-step procedure to correct for sample selection, a larger sample for the second-step estimation would have benefited the research.

 $^{^{20}}$ In the first 3 months of the survey, about 55% of the respondents had been vaccinated, but this number rose to 82% in the last 3 months of the survey.

References

- Agranov M, Elliott M, Ortoleva P (2021) The importance of social norms against strategic effects: the case of Covid-19 vaccine uptake. *Economics Letters*, 206:109979. https://doi.org/10.1016/j.econlet.2021.109979
- Agrawal V, Cantor J, Sood N, Whaley C (2023) The impact of COVID-19 shelter-in-place policy responses on excess mortality. *Health Economics*, 32:2499–2515. https://doi.org/10.1002/hec.4737
- Angerer S, Glätzle-Rützler D, Lergetporer P, Rittmannsberger T (2023) How does the vaccine approval procedure affect COVID-19 vaccination intentions? *European Economic Review*, 158:104504. https://doi.org/10.1016/j.euroecorev.2023.104504
- Banerjee AV (1992) A simple model of herd behavior. *The Quarterly Journal of Economics*, 107:797–817. https://doi.org/10.2307/2118364
- Barber A, West J (2022) Conditional cash lotteries increase COVID-19 vaccination rates. *Journal of Health Economics*, 81:102578. https://doi.org/10.1016/j.jhealeco.2021.102578
- Bauer T, Epstein GS, Gang IN (2002) Herd effects or networks? The location choice of Mexican immigrants in the US. IZA Discussion Paper No. 551. https://www.iza.org/publications/dp/551/herd-effects-or-migration-networks-the-locationchoice-of-mexican-immigrants-in-theus#:~:text=Our%20empirical%20results%20show%20that,or%20a%20%E2%80%9Crepeat

<u>%E2%80%9D%20migrant</u>. Accessed 6/1/2024.

Bekiros S, Jlassi M, Lucey B, Naoui K, Uddin GS (2017) Herding behavior, market sentiment and volatility: will the bubble resume? *The North American Journal of Economics and Finance*, 42:107–131. https://doi.org/10.1016/j.najef.2017.07.005

- Bennett D, Chiang CF, Malani A (2015) Learning during a crisis: the SARS epidemic in Taiwan. Journal of Development Economics, 112:1–18. https://doi.org/10.1016/j.jdeveco.2014.09.006
- Bikhchandani S, Hirshleifer D, Welch I (1992) A theory of fads, fashion, custom, and cultural change as informational cascades. *Journal of political Economy*, 100:992–1026
- Böhm R, Betsch C, Korn L (2016) Selfish-rational non-vaccination: experimental evidence from an interactive vaccination game. *Journal of Economic Behavior & Organization*, 131:183–195. https://doi.org/10.1016/j.jebo.2015.11.008
- Brito DL, Sheshinski E, Intriligator MD (1991) Externalities and compulsary vaccinations. *Journal of Public Economics*, 45:69–90. https://doi.org/10.1016/0047-2727(91)90048-7
- Carrieri V, Madio L, Principe F (2019) Vaccine hesitancy and (fake) news: quasi-experimental evidence from Italy. *Health Economics*. 28:1377–1382. https://doi.org/10.1002/hec.3937
- Cohen MJ, Brezis M, Block C, Diederich A, Chinitz D (2013) Vaccination, herd behavior, and herd immunity. *Medical Decision Making*, 33:1026–1038. https://doi.org/10.1177/0272989X13487946
- Costa-Font J, Rudisill C, Harrison S, Salmasi L (2023) The social value of a SARS-CoV-2 vaccine: willingness to pay estimates from four western countries. *Health Economics*. 32:1818–1835. https://doi.org/10.1002/hec.4690
- Demirer R, Kutan AM, Chen CD (2010) Do investors herd in emerging stock markets?: Evidence from the Taiwanese market. *Journal of Economic Behavior & Organization*, 76:283–295. https://doi.org/10.1016/j.jebo.2010.06.013
- Dubé E, Laberge C, Guay M, Bramadat P, Roy R, Bettinger JA (2013) Vaccine hesitancy: an overview. *Human Vaccines & Immunotherapeutics*, 9:1763–1773. https://doi.org/10.4161/hv.24657

- Easterlin RA, O'Connor KJ (2023) Three years of COVID-19 and life satisfaction in Europe: a macro view. Proceedings of the National Academy of Sciences, 120(19):e2300717120. https://doi.org/10.1073/pnas.2300717120
- Epstein GS (2008) Herd and network effects in migration decision-making. *Journal of Ethnic and Migration Studies*, 34:567–583. https://doi.org/10.1080/13691830801961597
- Epstein, GS, Gang IN (2024). Herding, taxpayer's rent seeking and endemic corruption. Journal of Economic Behavior & Organization, 217, 533-546.
- Epstein GS, Heizler O (2006) Immigrants during 1990's from Former Soviet Union: herd effect and network externalities. *The Economic Quarterly*, 53:166–201 (in Hebrew)
- European Social Survey European Research Infrastructure (ESS ERIC). (2023). ESS10 integrated file, edition 3.2 [Data set]. Sikt - Norwegian Agency for Shared Services in Education and Research. https://doi.org/10.21338/ess10e03_2
- Giulietti C, Vlassopoulos M, Zenou Y (2023) When reality bites: local deaths and vaccine takeup. *European Economic Review*, 156:104463. https://doi.org/10.1016/j.euroecorev.2023.104463
- Grüner S, Krüger F (2021) The intention to be vaccinated against COVID-19: stated preferences before vaccines were available. *Applied Economics Letters*, 28:1847–1851. https://doi.org/10.1080/13504851.2020.1854445
- Gul F, Lundholm R (1995) Endogenous timing and the clustering of agents' decisions. Journal of Political Economy, 103:1039–1066
- Hale T, Angrist N, Goldszmidt R et al (2021) A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature Human Behaviour*, 5:529–538. https://doi.org/10.1038/s41562-021-01079-8

- Hierro LÁ, Patiño D, Atienza P, Garzón AJ, Cantarero D (2023) The effect of altruism on COVID-19 vaccination rates. *Health Economics Review*, 13:2. https://doi.org/10.1186/s13561-022-00415-6
- Huang C, Li C, Liu F, Xu R (2023) Vaccination and risky behaviors: evidence from the hepatitis B vaccination campaign in China. *Journal of Population Economics*, 36:2549–2580. https://doi.org/10.1007/s00148-023-00942-4
- Kairiza T, Kembo G, Chigusiwa L (2023) Herding behavior in COVID-19 vaccine hesitancy in rural
 Zimbabwe: the moderating role of health information under heterogeneous household risk
 perceptions. *Social Science & Medicine*, 323:115854.
 https://doi.org/10.1016/j.socscimed.2023.115854
- Kennedy RE (2002) Strategy fads and competitive convergence: an empirical test for herd behavior in prime-time television programming. *The Journal of Industrial Economics*, 50:57–84. https://doi.org/10.1111/1467-6451.00168
- Keynes JM (1936) The general theory of employment, interest and money. Palgrave Macmillan, London
- Kovacic M, Orso CE (2023) Who's afraid of immigration? The effect of economic preferences on tolerance. *Journal of Population Economics*, 36:1901–1940. https://doi.org/10.1007/s00148-023-00947-z
- Lepinteur A, Borga LG, Clark AE, Vögele C, D'Ambrosio C (2023) Risk aversion and COVID-19 vaccine hesitancy. *Health Economics*. 32:1659–1669. https://doi.org/10.1002/hec.4693
- Mathieu E, Ritchie H, Rodés-Guirao L et al (2020) Coronavirus pandemic (COVID-19). Our World in Data. <u>https://ourworldindata.org/coronavirus</u>. Accessed 6/1/2024.
- McPhedran R, Toombs B (2021) Efficacy or delivery? An online Discrete Choice Experiment to explore preferences for COVID-19 vaccines in the UK. *Economics letters*, 200:109747. https://doi.org/10.1016/j.econlet.2021.109747

- Moretti E (2011) Social learning and peer effects in consumption: evidence from movie sales. *Review* of *Economic Studies*, 78:356–393. https://doi.org/10.1093/restud/rdq014
- Pelegrin-Borondo J, Arias-Oliva M, Almahameed AA, Román MP (2021) Covid-19 vaccines: a model of acceptance behavior in the healthcare sector. *European Research on Management and Business Economics*, 27:100171. https://doi.org/10.1016/j.iedeen.2021.100171
- Robertson C, Schaefer KA, Scheitrum D (2021) Are vaccine lotteries worth the money? *Economics Letters*, 209:110097. https://doi.org/10.1016/j.econlet.2021.110097
- Scharfstein DS, Stein JC (1990) Herd behavior and investment. *The American Economic Review*, 80:465–479
- Soofi M, Najafi F, Karami-Matin B (2020) Using insights from behavioral economics to mitigate the spread of COVID-19. *Applied health economics and health policy*, 18:345–350. https://doi.org/10.1007/s40258-020-00595-4
- Sorensen AT (2006) Social learning and health plan choice. *The Rand journal of economics*, 37:929–945. https://doi.org/10.1111/j.1756-2171.2006.tb00064.x
- Wiśniowska K, Żuradzki T, Ciszewski W (2022) Value choices in European COVID-19 vaccination schedules: how vaccination prioritization differs from other forms of priority setting. *Journal* of Law and the Biosciences, 9:2. https://doi.org/10.1093/jlb/lsac026
- World Health Organization (2020) COVID-19: WHO European region operational update epi weeks 31–32 (27 July–9 August). *World Health Organization*, Geneva
- World Health Organization (2023) WHO Regional Office for Europe COVID-19 operational update.A year in review: 2022 (No. WHO/EURO: 2023-7636-47403-69639). World Health Organization, Regional Office for Europe
- Zamfir IC, Iordache AMM (2022) The influences of covid-19 pandemic on macroeconomic indexes for European countries. *Applied Economics*, 54:4519–4531. https://doi.org/10.1080/00036846.2022.2031858

Appendix A

	Definition	Mean	SD
Herd	The change in the share of vaccinated	0.368	0.517
	individuals in the country occurring in the		
	week preceding the individual's interview ^a		
Sociodemographic	controls:		l
Age	The respondent's age	50.050	18.499
Education	The respondent's years of education	13.262	4.206
Female	A dummy variable, 1 – female, 0 – male	0.515	0.499
Religiosity level	"How religious would you say you are?"	4.388	3.132
	Answers range from 0 – not at all religious to		
	10 – very religious		
Immigrant	A dummy variable, 1 – for a respondent who	0.108	0.310
	was not born in the country, 0 – otherwise		
General trust	Average of the three questions: "Most people	5.305	1.890
	can be trusted OR you cannot be too careful";		
	"Most people try to take advantage of you OR		
	try to be fair"; "Most of the time, people are		
	helpful OR people mostly look out for		
	themselves." Answers range from the lowest		
	trust level to the highest (0 to 10,		
	respectively)		
Subjective health s	tatus:		I

Table A1 Variable definitions and descriptive statistics

Very good health	A dummy variable for subjective general	0.254	0.435
	health, 1 - very good, 0 - otherwise		
Bad health	A dummy variable for subjective general	0.064	0.244
	health, 1 – bad/very bad, 0 – otherwise		
	Omitted category – good/fair		
COVID-19 illness	history:	<u> </u>	<u> </u>
Positive COVID	A dummy variable, 1 – yes, tested positive for	0.232	0.422
test	COVID-19, 0 – otherwise		
Thought to have	A dummy variable, 1 – yes, I think I had	0.056	0.230
had COVID	COVID-19 but was not tested/did not test		
	positive, 0 – otherwise.		
	Omitted category – no		
Pandemic-related for	eatures:	L	I
Omicron dummy	A dummy variable, 1 – respondent interviewed	0.173	0.378
	in January or February 2022, 0 – otherwise		
Dummy 2021	A dummy variable, 1 – respondent interviewed	0.523	0.499
	in 2021, 0 – otherwise		
Stringency	The difference between the stringency index	10.087	10.910
difference	for nonvaccinated vs. vaccinated ^b		
Dummy till July	A dummy variable, 1 – respondent interviewed	0.091	0.288
2021	in or before July 2021, 0 – otherwise		
Share	Percentage of the vaccinated population ^a	72.37	15.602

^a Data retrieved from OWID.

^b Data retrieved from OxCGRT.

Appendix B

Table B1 The probability of being unvaccinated when surveyed: a first-step estimation of a

Probit model with sample selection

	1
Dummy till July 2021	0.252**
	(0.106)
Controls:	
Sociodemographic	V
Trust	V
Country fixed effects	V
rho	-0.850***
	(0.088)
Wald test of independent	15.51***
equations	
Selected observations	8,239
Unselected observations	22,408
Log pseudolikelihood	-10,15.72

Notes: Sociodemographic controls include age, education, gender, religiosity level, and a dummy variable for a first-generation immigrant. Standard errors are in parentheses and are clustered at the country level. ***.**Significant at the 1% and 5% level, respectively.

Appendix C

	1	2	3	4	5
Herd	0.128***	0.136***	0.122***	0.124***	0.123***
	(0.030)	(0.029)	(0.026)	(0.027)	(0.034)
Age	0.009***	0.009***	0.008***	0.008***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Education	0.027***	0.027***	0.028***	0.027***	0.028***
	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)
Female	-0.014	-0.012	-0.019	-0.022	-0.035
	(0.028)	(0.027)	(0.025)	(0.026)	(0.029)
Religiosity level	-0.035***	-0.036***	-0.033***	-0.033***	-0.033***
	(0.011)	(0.011)	(0.010)	(0.010)	(0.011)
Immigrant	-0.249***	-0.236***	-0.218***	-0.218***	-0.221***
	(0.057)	(0.054)	(0.053)	(0.052)	(0.054)
General trust	0.074**	0.074**	0.077**	0.078**	0.079**
	(0.037)	(0.034)	(0.034)	(0.034)	(0.036)
Very good health		-0.102*	-0.107**	-0.107**	-0.112**
		(0.055)	(0.048)	(0.047)	(0.054)
Bad health		-0.319*	-0.290**	-0.290**	-0.286*
		(0.170)	(0.142)	(0.143)	(0.155)
Positive COVID test			-0.122	-0.120	-0.115
			(0.090)	(0.090)	(0.098)

Table C1 The full results of the estimation in Table 1

Thought to have had			-0.215***	-0.215***	-0.220***	
COVID			(0.075)	(0.075)	(0.074)	
Omicron				-0.115**		
				(0.052)		
Dummy 2021					-0.030	
					(0.097)	
Stringency difference					-0.010	
					(0.007)	
Stringency difference					0.012*	
*Dummy 2021					(0.007)	
Constant	0.286	0.325	0.372	0.372	0.371	
	(0.270)	(0.260)	(0.267)	(0.264)	(0.239)	
Country fixed effects	V	V	V	V	V	
Observations	8,377	8,371	8,239	8,239	7,857	
Log pseudolikelihood	-10,283.1	-10,257.5	-10,135.7	-10,133.0	-9,998.0	
Notaci Standard among are in parentheses and are alustared at the country law						

Notes: Standard errors are in parentheses and are clustered at the country level. ****,**,*Significant at the 1%, 5%, and 10% level, respectively.

Appendix D

	1	2	3	4
	One week	Two weeks	Three weeks	One month
Herd	0.124***	0.061***	0.041***	0.028***
	(0.027)	(0.013)	(0.008)	(0.005)
Observations	8,239	8,239	8,239	8,239
Log pseudolikelihood	-10,133.0	-10,133.6	-10,133.8	-10,134.8

 Table D1 Herd behavior and the willingness to vaccinate, using different definitions for the herd variable: a second-step estimation of a Probit model with sample selection

Notes: All estimations include the following controls: age, education, gender, religiosity level, a dummy variable for a first-generation immigrant, trust, subjective health status, COVID-19 illness history, Omicron dummy, and country fixed effects. Standard errors are in parentheses and are clustered at the country level. ***Significant at the 1% level.



Fig. D1 Herd coefficients when shifting the timing of the herd variable. Herd variables are defined as the change in the share of vaccinated individuals in the first, second, and third week preceding the respondent's interview. All estimations include the following controls: age, education, gender, religiosity level, a dummy variable for a first-generation immigrant, trust, subjective health status, COVID-19 illness history, Omicron dummy, and country fixed-effects; 95% confidence intervals are also depicted.

 Table D2 Herd behavior and the willingness to vaccinate: heterogeneous effect for different

 shares of vaccinated people (different cut-off points); a second-step estimation of a Probit

 model with sample selection

	1	2	3	4
Herd	0.107***	0.142***	0.131***	0.137***
	(0.024)	(0.025)	(0.024)	(0.022)
Herd*medium share 45–	0.014			
70%	(0.038)			
Herd*high share >70%	0.085			
	(0.060)			
Herd*medium share 35–		-0.063***		
70%		(0.023)		
		0.040		
Herd*high share >70%		0.043		
		(0.055)		
		(0.055)		
			0.052*	
Herd*medium share 40–			-0.052*	
750/			(0.020)	
/5%			(0.020)	
I Jand * high abons >750/			0.011	
neru mgn snare ~/ 5%			0.011	
			(0.075)	
			(0.075)	

Herd*medium share 35–				-0.074***
65%				(0.018)
Herd*high share >65%				0.088
				(0.067)
Observations	8,239	8,239	8,239	8,239
Log pseudolikelihood	-10,132.4	-10,131.3	-10,131.0	-10,129.6

Notes: All estimations include the following controls: age, education, gender, religiosity level, a dummy variable for a first-generation immigrant, trust, subjective health status, COVID-19 illness history, Omicron dummy, and country fixed effects. Standard errors are in parentheses and are clustered at the country level. ***.*Significant at the 1% and 10% level, respectively.

 Table D3 Herd behavior and the willingness to vaccinate: 2021 sample; a second-step

 estimation of a Probit model with sample selection

	1
Herd	0.101***
	(0.018)
Controls:	
Sociodemographic	V
Trust	V
Subjective health status	V
COVID-19 illness	V
history	
Stringency difference	
Country fixed effects	V

Observations	6,778
Log pseudolikelihood	-5,781.2

Notes: Sociodemographic controls include age, education, gender, religiosity level, and a dummy variable for a first-generation immigrant. Standard errors are in parentheses and are clustered at the country level. ***Significant at the 1% level.