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Research article

Willingness to COVID-19 vaccination: Empirical evidence from EU

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ABSTRACT

The unforgettable COVID-19 shock is most likely to be reversed by a viable vaccination strategy. In this paper, we investigate willingness to be vaccinated (WTV) against the COVID-19. Current trends suggest that only around 73% of EU inhabitants (15 and +) were immunized, with more than 104 million people still warranted to be immunized. Vaccine reluctance is a key impediment to conducting immunization programs in the setting of a pandemic. We provide first of its kind empirical evidence on the citizens (N = 11,932) of the EU-27 by employing the recent data from the European Commission. Based on the survey responses, controlling for the correlations in the error terms, we utilize a simulated multivariate probit regression model. Our results show that amongst all the statistically significant drivers of the WTV, the positive perception (vaccination works and has no side effects); R&D information (clarity on how vaccination is developed, tested, authorized) has the largest impact on the WTV. We find that the group of variables on social feedback (Positive perception; social adoption and pressure), and on trustworthy sources of information (R&D info; medical advice) are to be considered for WTV policy. The counteracting policy gaps that act against WTV include vaccination governance dissatisfaction, perception of long-term side effects, growing mistrust in information sources, uncertainty between safety and efficacy, education level, and risky age group. Strategies based on the outcomes of this study are needed to address public acceptance and willingness to vaccinate during a pandemic. This research is novel and offers authorities in-depth insights into the challenges and solutions regarding the COVID-19 pandemic and thus to its end via stimulation of the WTV.

1. Introduction

The COVID-19 pandemic will always be an unforgettable global shock to our way of life. After the acceptance of the worst pandemic reality and settlement of the panic, the world impatiently waited for the development of the COVID-19 vaccination as the only viable long-term solution [1–3]. A global act of multilateralism against the constraints to supply and ensure equitable access to tests, treatments, and vaccines the COVID-19 tools accelerator (ACT) is put in place [4]. It proposes a total of US $38.1 billion in budget and motivates high-income countries to make a financial investment in its mission. Fast forward to 2021, pandemic continues, and lockdowns are still enforced but the vaccination era has also begun. COVAX the responsible authority on global COVID-19 vaccination

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from the ACT agreement set its aim to administer at least 2 billion doses to the most vulnerable in low and middle-income parts of the world, by the end of 2021 [5]. A recent study measures that due to the interdependent trade and economic linkages the global economy can face a loss of US$ 9.2 trillion, in the worst-case scenario where vaccinations are not provided to the developing world [6]. In a scenario, where half of the developing world population is vaccinated, a global loss of US$ 3.8 trillion is expected. The US$ 1.9 trillion of it is lost in GDP of the developed economies.

The global campaign to vaccinate everyone and make COVID-19 a ‘people’s vaccination’ by removing its patents [7] can be confessed as an economic rationale, rather than a mere humanitarian one [6]. Immunologists advocate reaching a so-called ‘herd-immunity’ that can minimize the chances of contraction drastically [8]. This herd immunity threshold increases along with an increase in the reproduction number i.e., how many are secondarily infected by the primary. At least 75% of the national population needs to be vaccinated assuming a reproduction number of 4. The world learned, and the end to the COVID-19 pandemic is set in sight and can now be navigated. By the end of September 2021, a 2.5 billion of the world population is fully vaccinated [9].

As the COVID-19 pandemic is still spreading throughout the globe, having a negative effect on economics, and sowing the seeds of geopolitical discontent, COVID-19 vaccinations is anticipated to put an end to the spread of the illness and return the world to its previous level of efficiency [10]. Unfortunately, in many parts of the world the public is divided on the issue of vaccination and many people are hesitant to get vaccinated. In the European Union (EU), 275 million from its 447 million citizens have only been fully vaccinated. This underachievement is also prevalent if, roughly, a non-risky population is not considered (see Fig. 1). If the fully vaccinated to population ratio for only risky population (15 and above) of the EU is estimated (vaccination quota), it shows that more than a quarter (27%) of EU citizens have refused to take vaccinations. Clearly, the EU does not lack access to doses, as the EU has actively made advance purchase agreements with individual vaccine producers [11]. Further demand for vaccinations also can be observed to be saturated and in a steep decline (see Fig. 2). As in our data 75% of sampled EU citizens agree that vaccines are the only way to end the pandemic, yet there is a lack of or hesitancy to be vaccinated.

In the study of public opinion and behavior, the emergence of infectious illnesses and the possibility for vaccination to prevent them is a rich topic [12]. In the last decade, researchers have focused their attention on some skepticism in people about the effectiveness and safety of vaccinations, as well as their apprehension about vaccination schedules [13–15]. Vaccine hesitancy among individuals is driven by various socio-economic and geo-political factors. Reduced vaccine acceptability among parents, as well as increased anti-vaccination sentiments among the wider population, represent substantial public health concerns since disease outbreaks typically need very high rates of vaccine compliance [16–18]. According to literature, socio-economic indicators also play a crucial role in driving the willingness to vaccinate [19].

COVID-19 vaccination rates have continued to decline even though more individuals are being vaccinated every day throughout the world, including among EU members [20]. Similarly, anti-vaccine sentiments have been growing recently which is matter of huge concerns especially EU member states [21,22]. Similarly, the policies of government related to vaccine mandates as requirements for schools and religious places have sparked debates and outcry from the public who opposed such policies. Vaccination policy has traditionally been non-partisan, however in the case of the current pandemic, issues surrounding vaccinations and associated policies are reflective of the potential politics of vaccines (and vaccination policy), which has resulted in a societal divide on the subject [23]. A part of the population favors vaccines and are vaccinated, while others are anti-vaccines and not willing to get vaccinated. As a result, it is causing challenges with vaccination administration and achieving herd immunity [20]. Similarly, it is not just the public but also the attitude of healthcare workers and medical professionals that has been analyzed [24–26]. Therefore, it is important to understand and study the attitude of average population towards vaccines and to analyze determining reasons driving the WTV.
Against this backdrop, a clear research question is: what drives the willingness to be vaccinated (WTV) amongst the EU citizens? Alternatively, equally important is the question: what can be done to promote it, if this is the goal and only viable strategy? Based on the statistics it is important to analyze what determines an individual’s willingness to get vaccinated and what factors need to be considered for the risky group to be vaccinated? In this research, we empirically analyze different factors that may increase individuals’ willingness to vaccination with the assumption that vaccinations are a viable solution to end the pandemic given the goals and intentions of the EU, which are politically, economically, socially and health motivated. We investigate these objectives of the study using novel EU-wide data [27].

The mandates and policies related to COVID-19 have led to polarization and politics on vaccination throughout the world [23, 28]. In the case of many countries including the EU, USA, Australia considerable portion of the population was still unvaccinated, which led to division between the authorities and the communities and separation within the communities. To study these issues in-depth, we provide novel empirical evidence, based on public opinion and perception. We also try to fill the gap between the policies of the EU member states and their citizens’ WTV.

WTV and “vaccine hesitation” (or “vaccine acceptance”) are likely to be complicated and multidimensional notions, as are most theoretically salient and politically controversial ideas (particularly those that represent human beliefs or attitudes) [29, 30]. It is critical to comprehend the reasons why society was divided on vaccines during COVID-19 pandemic. Addressing the joint deterministic nature of our dependent variables, we employ the maximum simulated likelihood multivariate probit model as our econometric approach [31]. Our empirical study is an important and novel contribution that uses this novel rich data on attitude of EU-27 citizens towards COVID vaccinations. Our empirical work contributes to vaccination hesitancy literature and has implications for EU and other countries.

2. Materials and methods

2.1. Data and methods

For our empirical analysis, we use the latest Flash Eurobarometer survey data from the European Commission on: “attitudes on vaccination against COVID-19” [27]. The survey interviewed 26,106 EU citizens aged 15 and above between the 21st of May 2021, and the 26th of May 2021. The survey was conducted in the national language via computer assistance. We focus on a sample of 11,932 observations by looking at the WTV of those who are planning to be vaccinated against those who have decided to never be vaccinated. Therefore, our empirical evidence sheds light on potential drivers and determinants of the demand of the COVID-19 vaccination.

Our binary determinants are constructed from the survey question: “You would be more eager to get vaccinated against COVID-19 if…”. There are multiple answers possible for this question, which causes a potential joint determination, hence, a multivariate model is employed (see next section). Our main binary variable is constructed from the survey question: “When would you like to get vaccinated against COVID-19?”. It takes the value of 1 if the respondent is willing to be vaccinated “As soon as possible”, “sometime in 2021”, “later”. The value is 0 if the response is “never”. Within the scope of this study, we do not discriminate the length of the intention to be vaccinated, therefore binary values have been assigned to understand WTV of European Citizens against those who refuse to take COVID-19 vaccination. A 37% of survey participants are already vaccinated, hence these responses are not of interest for our analysis. Our control variables are vaccine strategy satisfaction employed by the institutions, fear, and perception of the pandemic.
and vaccines, which also correspond to literature studies [32–36]. In addition, we control for the demographic variables such as being in a risky age group, gender, and higher education. Finally, we control for the country-specific effects. A description of our constructed variables is available in Table 1.

The recent literature on compliance to COVID-19 measures suggests that pre-pandemic high-trust levels play an important part in the EU region [37]. The countermeasure strategies to manage pandemic has been found influential on trust in government [38,39]. The implications of trust in institutions are also studied in healthcare [40] and how pandemics can be best managed with trust in government [35]. Importantly, viable countermeasures such as vaccine-related hesitancy is mainly affected by a lack of trust in institutions [36]. Following this, we control for satisfaction attitudes towards governments and the EU’s vaccination strategy in our model. The fear of infection and mortality is an anthropological fact that erupts in several forms and shapes related to any disease, more so, in today’s interconnected world [32,33]. It may not be a psychological state that may allow for rational decision-making. For example, a plausible study has already shown that psychological factors and state of mind including anxiety may have diverse impacts on WTV [34]. Furthermore, a willingness cannot be determined by forced personal or social fear rather should be determined based on motivation from positive perceptions and attitudes. Therefore, we control for personal and social levels of fear that may influence WTV. These two variables also consider the medical history related to COVID-19. The perception of parents, as decision-makers is crucial for vaccinating their children [41,42]. We proxy this perception as a family perception towards vaccination safety, effectiveness, and its implications on WTV. It is plausible to expect that a family’s health literacy as set by the parents, in such a novel health crisis will be of relevance to make appropriate group decision. Furthermore, a general perceived safety and efficacy of vaccination plays a role in the acceptance of vaccination [43]. This general attitude is perhaps resistant to COVID-19 WTV as vaccinations for

| Drivers | Labels | Definition | Values |
|---------|--------|------------|--------|
| Social pressure | Socialpressure | You see more people around you do it | 1 if mentioned; 0 otherwise |
| Positive perception | Positiveperception | More people have been vaccinated and we see that it works and that there are no major side effects. | 1 if mentioned; 0 otherwise |
| Social adoption | Socialadoption | The people that recommend the vaccines are vaccinated themselves | 1 if mentioned; 0 otherwise |
| Medical advice | Medicaladvice | Your doctor(s) recommend(s) you to do so | 1 if mentioned; 0 otherwise |
| EU produced | EUproduced | Vaccines are developed in the EU | 1 if mentioned; 0 otherwise |
| R&D info | R&Dinfo | There is full clarity on how vaccines are being developed, tested, and authorized | 1 if mentioned; 0 otherwise |

**Main variable**

| Willingness to be vaccinated (WTV) | WTV | When would you like to get vaccinated against Covid-19? | 1 if As soon as possible; sometime in 2021; Later 0 if Never |

**Control variables**

| Satisfaction in government vaccination strategy | Govsatisfaction | Following institutions have handled the vaccination strategy | 1 if very satisfied; fairly satisfied |
| Satisfaction in the EU vaccination strategy | EUsatisfaction | 0 Fairly dissatisfied; not satisfied at all |
| Social fear | Socialfear | Tell if it applies: You know people who have been ill because of COVID-19 | 1 Yes; 0 No |
| Personal fear | Personalfear | Tell if it applies: You have been ill because of COVID-19 | 1 Yes; 0 No |
| Family perception | Familyperception | Tell if it applies: You have been vaccinated as a child | 1 Yes; 0 No |
| Vaccine safety attitude | Vaccinesafetyattitude | What extent agree or disagree: Vaccines are safe | 1 Totally agree; tend to agree |
| Vaccine efficacy attitude | Vaccineefficacyattitude | 0 Tend to disagree; totally disagree |
| Gender | Gender | 1 Male; 0 Female |
| Higher education (in years) | Highereducation | 1 20 years and older; Still in full time education |
| | | 0 Up to 15 years; 16–19 years; Never been in full time education |
| Risky age group | Riskyagegroup | 1 55 years and older; 0 15–54 years old |
| Country dummy | Yes | |
COVID-19 are developed with an abnormal process (rapid development, testing and authorization) and emergency use approvals due to the global urgency [44,45]. Moreover, conflicting information on COVID-19 vaccines is also an underlying reason to control for it [46]. These three variables act as a proxy for controlling medical history of the respondents. Evidence shows that medical history in terms of diseases including COVID-19 play a crucial role in determining WTV among individuals [47]. Considering gender, we take into account the medical evidence that COVID-19 is more infectious to men as compared to women [48,49]. Similar justification terms correlated across the equations. The system of equations is jointly determined by model design. For each of the equations: the above matrix outlines eight joint probabilities corresponding to the possible combinations of successes ($y_{im} = 1$) and failures ($y_{im} = 0$). In the case of $\Pr(y_{1} = 1, y_{2} = 1, y_{3} = 1)$ than

$$= \Pr(e_{1} \leq \beta_{1}X_{1}, e_{2} \leq \beta_{2}X_{2}, e_{3} \leq \beta_{3}X_{3})$$

$$= \Pr(e_{2} \leq \beta_{2}X_{2} | e_{1} \leq \beta_{1}X_{1}) \times \Pr(e_{3} \leq \beta_{3}X_{3} | e_{1} \leq \beta_{1}X_{1}) \times \Pr(e_{1} \leq \beta_{1}X_{1})$$

The expression shows conditioning on error terms (unobservable variables) that are correlated with each other [31]. For seven other outcomes conditionality is similar, and for $M = 6$ where $2^6$ as many combinations are possible. For an approximation of conditional distribution, using Cholesky decomposition for the estimation of the log-likelihood function, decomposed unconditional probabilities are defined of standard normal variates. This simplifies the calculation of likelihood function to the simulated estimation of decomposed univariate standard normal distributions by taking random draws that further compute multivariate probability [31]. The simulator removes the potential for small sample and simulation biases by suggesting that a square root of the number of observations (here: $N = \sqrt{110} = 10.5$) is provided as number of draws. The process is computationally intensive and requires several hours where draws (110) × number of equations (6), temporary variables (660) are created. Using post estimation options in STATA-16.1, we calculate the marginal success probability for each equation. Following this we estimate a system of equations:

$$Social \ pressure = \alpha_{1} + \beta_{1}WTV + \delta_{1}Controls + \epsilon_{1}$$

$$Positive \ perception = \alpha_{2} + \beta_{2}WTV + \delta_{1}Controls + \epsilon_{2}$$
3. Results

In Table 2 we present our sample descriptive statistics. WTV appears to be skewed distributed towards the immediate and hesitant acceptance, with only 18% never willing to be vaccinated. Positive perception and R&DInfo are the first and most mentioned set of driving factors followed by medical advice and social adoption according to the survey. While social pressure and EUproduced are the least mentioned driving factors. There is almost a polarization in our sample to be satisfied with the vaccination strategy of the local government or the EU. An almost three-quarters of the respondents are confronted by social fear. On the other hand, personal fear (13%) is drastically lower as compared to social fear (74%). The EU families have a strong positive perception of the vaccination (90%) and have vaccinated their children. Similarly, general attitudes towards the safety and efficacy of vaccinations are also very high-79% and 84% respectively. We have an almost equal representation of both genders (51% males to 49% females) in the sample. A well above the average of almost 64% citizens have obtained 20 or more years of education, or currently are continuing it. And almost 22% of citizens are in the risky age group.

In Appendix A we provide the pairwise Pearson’s coefficients of correlation to describe the interdependence of the variables. All the variables are in their acceptable range and show no sign of multicollinearity that may cause over-specification and inconsistency of the estimates.

In Table 3 we have provided our results using the outlined econometric methodology while in Fig. 3 we show the visual summary of the main results. With a highly statistically significant result of the log-likelihood ratio test of rho, we can conclude that our econometric approach is correctly specified and the null hypothesis ($\rho = 0$) can be rejected. All the individual rhos are also positive and statistically highly significant and show that joint determination is to be addressed. Due to limited interpretation possibilities of the probit model, post-estimates of marginal effects are usually done. However, the employed simulated method does not support any validated post estimates using STATA-16.1. Limited by the individual average marginal effects, the simulation allows for post-estimates on the marginal success probability ($\Pr(\text{depvariable}) = 1$) for each equation in Table 4.

4. Discussion

As argued, our main results (Table 3) are in line with the findings of existing literature studies [22, 38, 53–55]. This study adds to the literature works by addressing the evidence-based policy making to combat COVID-19 via vaccination strategy in the context of EU-27. Given the high transmissibility and mortality rates of Delta variant, our results are likely to be driven by these risks. These outcomes may not be replicated in the case of Omicron variant which is considered to be more transmissible and was earlier expected to be more lethal as compared to the Delta variant [56–58].

Our results show that vaccine compliance is positively driven by the dependent variables. In combination with mean marginal predicted probabilities in Table 4, the largest average contribution is from the positive perception (36%) and secondarily from the
infected are concerned with long-term effects of COVID-19 vaccinations [70]. This behavior can be further understood by analyzing while the dissatisfaction in the local supply can only be attributed to the local government.

Perception that there are no side effects. It is plausible to infer that these naturally immune and recovered individuals after being 

by knowing people who have been infected has a positive impact on positive perception. The negative counteracting effect on WTV can 

personal fear developed as an infected individual has a negative effect on positive perception. On the other hand, social fear indicated 

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perception and R

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The second cluster of drivers of WTV based on the sources of information (R

Finally, proximity of the vaccinations to be produced in the EU (12%), which may be an indicator of a positive reliance and trust in the 

from already vaccinated individuals encourages others to get vaccinated. Similarly, social pressure (16%) of observing more in 

Table 3

| VARIABLES | 1 Social pressure | 2 Positive perception | 3 Social adoption | 4 Medical advice | 5 EU produced | 6 R&Dinfo |
|-----------|-----------------|-----------------------|-----------------|----------------|--------------|---------|
| WTV       | 0.895***        | 0.706***              | 0.565***        | 0.778***       | 0.740***     | 0.424*** |
| Govsatisfaction | 0.125***  | -0.0842**             | 0.0697**        | 0.0727**       | 0.0413       | -0.0774** |
| ELsatisfaction | 0.183***  | 0.0421                 | 0.0713**        | 0.106***       | 0.210***     | -0.0236 |
| Socialfear | 0.0623**        | 0.117***              | 0.0340          | 0.0490*        | 0.0148       | 0.0945** |
| Personalfear | 0.0132   | -0.153***             | 0.0755          | 0.0871**       | -0.0273      | -0.0291 |
| Familyperception | -0.221*** | 0.0825*               | -0.0985**       | -0.158***      | -0.232***    | 0.169*** |
| Vaccinesafetytitude | 0.0285   | 0.0511                | 0.0197          | 0.0990***      | -0.0280      | -0.126** |
| Vaccineeficacyattitude | 0.0361   | 0.270***              | -0.0156         | 0.0865         | 0.0141       | 0.191*** |
| Gender    | 0.0569*         | -0.0904***            | -0.0539*        | 0.0973***      | 0.203***     | -0.0571** |
| Highereducation | -0.0284   | 0.0755**              | -0.0245         | -0.0474*       | 0.0426       | 0.0477* |
| Riskyagegroup | -0.121*** | -0.0773**             | -0.156***       | 0.101**        | -0.0732      | -0.0823** |
| Constant  | -2.010***       | -1.147***             | -1.318***       | -1.744***      | -2.095***    | -0.795*** |
| Observations | 11.932   | 11.932                | 11.932          | 11.932         | 11.932       | 11.932   |

**Clustered standard errors by country in parentheses (27 clusters).***p < 0.01, **p < 0.05, *p < 0.1.

R&Dinfo (32%). The literature studies guide us that a range of swirling sentiments combined with unstoppable misinformation, novel uncertainty, and risk of mortality may result in the adoption of the ‘wait-and-see’ strategy and to go to the trustworthy sources of information [24,59–65]. According to the estimates of this research, the primary source of information is the research and development information of the vaccinations followed by doctors as the secondary source of information (20%). It is the limitation of the survey that it does not take into account a crucial source of information—social media, however the scientific information that is likely to effect WTV [66,67] is part of the survey. The results also suggest that the social adoption (18%) in terms of the recommendation from already vaccinated individuals encourages others to get vaccinated. Similarly, social pressure (16%) of observing more individuals closer to the respondents getting vaccinated appears to act as a replication effect and feedback mechanism to stimulate WTV. Finally, proximity of the vaccinations to be produced in the EU (12%), which may be an indicator of a positive reliance and trust in the quality of the vaccination, plays a positive role in driving WTV.

In order to discuss the implications of the results, two clusters of drivers are suggested. The first cluster of drivers of WTV includes a combined role of confirmation that there are no side-effects plus encouraging and compulsive positive feedback from the society. This also complements previous findings that vaccines safety and side-effects determine the WTV, for example, in the case of Vietnam [68]. The second cluster of drivers of WTV based on the sources of information (R&Dinfo and medical advice) most likely with high trust. Clearly, a much-needed policy implication, as already emphasized in the literature, is to provide trustworthy information (at various levels) that will eventually trickle down in creating positive feedback on the effective acceptance of the vaccination [66,67,69].

However, these implications are counteracted by some of the variables (Fig. 3). Our control variables show that the positive perception and R&Dinfo predict to be negatively affected if there is a lack of satisfaction in the government’s vaccination strategy. This can be possibly described as a criticism on the effective governance to supply the vaccination to the general population. This may be due to the absence of supply in the presence of demand. This effect can be further studied by accounting for the insignificance of the satisfaction in the EU’s vaccination strategy. This perhaps indicates that the supply is satisfactorily managed by the EU institutions while the dissatisfaction in the local supply can only be attributed to the local government.

A study shows the negative impact of psychological factors including anxiety and stress disorder on WTV [34]. In case of this study, personal fear developed as an infected individual has a negative effect on positive perception. On the other hand, social fear indicated by knowing people who have been infected has a positive impact on positive perception. The negative counteracting effect on WTV can be explained that the infected, likely hospitalized and recovered from COVID-19 are not impacted by any of our drivers and reject the perception that there are no side effects. It is plausible to infer that these naturally immune and recovered individuals after being infected are concerned with long-term effects of COVID-19 vaccinations [70]. This behavior can be further understood by analyzing
the positive and statistically significant impact of the personal fear on medical advice. The possible interpretation suggests that these are the recovered who show WTV only due to medical advice under hospitalization [71].

The variable family perception that considers family’s health literacy shows that it positively drives WTV, if R&Dinfo is readily available. These families also rely on positive perception of the society to analyze the side-effects of the vaccination, however, less so as compared to its reliance on R&Dinfo. For the remaining variables, family perception counteracts WTV. Family, as a unit of collective decision-making, rejects and disregards all other sources of feedback from society and do not rely on medical advice and EU produced proximity. This probably emphasizes the importance of a family as a source of screening information based on suitable health literacy and education, especially due to novel uncertainty linked with COVID-19 pandemic and related vaccinations [72].

Table 4
Mean marginal success probability of each equation.

| Variable       | Obs  | Mean | Std. Dev. | Min  | Max  |
|----------------|------|------|-----------|------|------|
| Social pressure| 11,932 | 0.160 | 0.088     | 0.005 | 0.464 |
| Positive perception | 11,932 | 0.368 | 0.121     | 0.030 | 0.622 |
| Social adoption | 11,932 | 0.184 | 0.071     | 0.019 | 0.407 |
| Medical advice  | 11,932 | 0.200 | 0.091     | 0.008 | 0.459 |
| EU produced     | 11,932 | 0.128 | 0.063     | 0.009 | 0.360 |
| R&Dinfo         | 11,932 | 0.327 | 0.090     | 0.057 | 0.594 |

Fig. 3. Visual summary of multivariate probit results.
Safety attitude towards the vaccinations creates a positive impact on WTV after taking medical advice. On the other hand, as soon as clarity on R&Dinfo is considered, the safety attitude becomes negative and counteracts WTV. This counteracting effect can be interpreted intuitively due to the abnormal development, testing and authorization of COVID-19 vaccination cycle. Therefore, in line with expectations, safety attitude turns negative and discourages WTV, which is in line with previous literature where vaccine safety was found to be a significant determinant for WTV in different part of the Asia Pacific region [10,68]. Even though COVID-19 vaccinations have an abnormal life cycle, they are still considered to be one of the viable and effective solution to the pandemic. Therefore, the vaccine efficacy attitude towards vaccination does not counteract but rather positively drives WTV by increasing the level of trust in R&Dinfo. This positive effect of efficacy is also estimated on creating positive perception in the society. These conflicting concerns between safety and efficacy have been visible in the literature, our results confirm it for COVID-19 vaccinations [68].

Our demographic variables show that the male survey participants mainly rely on medical advice and trust in EU produced vaccinations, along with a smaller extent of dependence on social pressure. Female participants are estimated to have counteracting impact on positive perception, R&Dinfo and social adoption. Such gender disparities are visible in the literature that investigates WTV [73]. As per the estimates, the higher education variable shows that to some extent it helps create a positive perception of the vaccinations and decodifying the R&Dinfo. However, interestingly it is discovered that higher education counteracts the medical advice. These results show that in the specific case of COVID-19, the possession of information decoding capabilities due to higher education does not lead to complete clarity of R&Dinfo. This is most likely due to the comparative safety concerns of the vaccination development that eventually leads to rejection of medical advice. Contrary to this, the elderly participants under the variable of risky age group counteract WTV in all of the driving factors with the only exception of medical advice. These risky participants have always been the primary focus of any vaccination strategy that is mediated by the local doctors. Moreover, due to their age, it can be expected that they share a rather higher level of trust in their doctors based on their frequent visitation and medical history of underlying diseases. Therefore, it is plausible to find these results that show a statistically significant dependence between risky age group participants and their doctors as their medical advisors.

Our results have identified counteracting gaps that are crucial to address WTV and may act as levers of policy formation. The gap between governance and WTV: citizens are estimated to be dissatisfied with the local vaccination governance and may refuse vaccination even if they have a positive perception of no side effects of the vaccination and have clarity on vaccination’s R&Dinfo. Trust levels have to be actively restored in the local government that may have been eroded due to misinformation or other factors [38]. The gap between hospitalization and WTV: by looking at the impact of the variable for personal fear that takes into account the WTV of those respondents who were infected by COVID-19, we can explain this gap. Those who were infected, most likely hospitalized, or recovered are in fear of the long-term effects of vaccinations. A naturally immune recovery has to be researched and maintained because the recovered will not show WTV, unless medically forced. The gap between family perception, information, and WTV: a family with a positive general perception of vaccinations, mistrusts most sources of information gathering and mainly relies on the clarity of vaccination development, testing, and its authorization process. Health literacy act as a filter to misinformation. R&D information has to be made public to debunk misinformation and increase trust. The gap between safety, efficacy, and WTV: safety may be counteracting but efficacy is driving WTV. The efficacy of vaccinations has to be balanced against safety concerns, the way it has always been in vaccine compliance. The gap between higher education and WTV: highly educated appear to be standing in the waiting line to be vaccinated. They take into account the abnormal development of the vaccination and seem to mistrust medical advice. A conflict of interest may be detached between the medical experts and the promotion of vaccinations combined with the elimination of the understandable safety concerns. The gap between risky age group, doctors, and WTV: the risky and the elderly have no acceptance of vaccinations unless the medical advice is given. This reliance on doctors is maybe for the best but probably lower level of social interactions as a safety measure may be another reason for the elderly to rely only on the doctors in their residencies and old age medical facilities. Our results validate many of the anecdotal observations during the COVID-19 pandemic. The role of trust in society and trustworthy information have emerged as the two conclusive pieces of the puzzle to ensure WTV.

5. Conclusions

In the midst of raging COVID-19 pandemic, only around 73% of EU inhabitants (15 and +) were immunized, with more than 104 million people still warranted to be immunized. Vaccine reluctance is one of the key impediments to conducting immunization programs in the setting of a pandemic. Our findings reveal that, of all the statistically significant determinants of WTV, positive perception (vaccination works and has no adverse effects); and R&D information (clarity on how the vaccine is created, tested, and authorized) on the vaccine’s adverse effects had the largest impact on WTV. Obtaining reliable and accurate information about available vaccinations is the most essential element that may enhance vaccination acceptability.

We find many counteracting factors, that have appeared in the polarized debate on WTV. These counteract factors are originated from the gaps between society, information, and levels of trust in these sources of information. There are safety concerns, but these concerns are overcome by the efficacy of vaccination. Higher education levels among the individuals also aid WTV to decipher valuable information related to the vaccines. Moreover, WTV is assisted and aided by medical advice in terms of elderly people as risky age group (55 and +). Our research is novel in the context of EU-27 and has implications for evidence-based policy debate. The current study offers authorities in-depth insights into the anticipated challenges and solutions regarding the COVID-19 pandemic and to its end via stimulation of the WTV.

In terms of study limitations, data availability for other countries was a subject of concern, which might be addressed in future research by external validation of our findings with a different group of countries. The data can be stratified by country or region and the different strategies that has been used for vaccination in each country or region can be analyzed and compared for heterogeneity
and robust outcomes. In addition, the implications of the study are limited to the Delta variant of COVID-19, that was the prevalent variant during the survey period. The emergence of new variants including the omicron and its relevant booster vaccinations may require further investigation. Moreover, because our control variables provide varied outcomes, further focused study, and statistical evidence on them may be conducted. Furthermore, the results of this study may have generalizability limits because it deals with behavioral aspects of individuals, which can be verified and adjusted in future vaccination studies based on post-crisis behavior.

Author contributions

1 Conceived and designed the experiments: A.A., I-U.R., N-N.
2 Performed the experiments: A.A.
3 Analyzed and interpreted the data: A.A.
4 Contributed reagents, materials, analysis tools or data: A.A. I.U.R., N-N.
5 Wrote the paper: A.A., I-U.R., N-N.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki.

Data availability statement

The survey data used in this article can be freely downloaded from the GESIS Data Archives of the Flash barometer launched by the European Commission (European Commission, 2021). All data used in this study can be downloaded from the relevant cited sources. Specific country datasets are contained in references (European Commission, 2021).

Code availability

The codes used to generate these analyses are available for use and can be accessed with formal request to the corresponding author (A.A).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Pearson’s coefficients of correlation matrix
| Variables        | (1)    | (2)     | (3)    | (4)    | (5)    | (6)    | (7)    | (8)    | (9)    | (10)   | (11)   | (12)   | (13)   | (14)   | (15)   | (16)   | (17)   |
|------------------|--------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| WTV              | 1.000  |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Socialpressure   | 0.160  | 1.000   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Positiveperception | 0.191  | 0.181   | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Socialadoption   | 0.115  | 0.246   | 0.214  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Medicaladvice    | 0.172  | 0.190   | 0.136  | 0.205  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |
| EUproduced       | 0.130  | 0.156   | 0.109  | 0.186  | 0.168  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |
| R&Dinfo          | 0.092  | 0.086   | 0.185  | 0.200  | 0.115  | 0.143  | 1.000  |        |        |        |        |        |        |        |        |        |        |
| Govsatisfaction  | 0.285  | 0.112   | 0.037  | 0.059  | 0.100  | 0.077  | 0.000  | 1.000  |        |        |        |        |        |        |        |        |        |
| EUsatisfaction   | 0.310  | 0.120   | 0.073  | 0.070  | 0.099  | 0.100  | 0.020  | 0.553  | 1.000  |        |        |        |        |        |        |        |        |
| Socialfear       | 0.057  | 0.013   | 0.054  | 0.024  | 0.020  | -0.002 | 0.053  | 0.004  | 0.037  | 1.000  |        |        |        |        |        |        |        |
| Personalfear     | 0.009  | 0.015   | -0.030 | 0.024  | 0.019  | 0.002  | 0.001  | 0.018  | 0.017  | 0.145  | 1.000  |        |        |        |        |        |        |
| Familyperception | 0.035  | -0.039  | 0.047  | -0.012 | -0.006 | -0.041 | 0.050  | 0.000  | -0.002 | 0.153  | -0.050 | 1.000  |        |        |        |        |        |
| Vaccinesafety    | 0.424  | 0.076   | 0.113  | 0.051  | 0.109  | 0.055  | 0.024  | 0.275  | 0.286  | 0.086  | 0.002  | 0.170  | 1.000  |        |        |        |        |
| Vaccineefficacy  | 0.416  | 0.076   | 0.136  | 0.048  | 0.103  | 0.053  | 0.057  | 0.242  | 0.263  | 0.127  | -0.003 | 0.209  | 0.670  | 1.000  |        |        |        |
| Gender           | 0.031  | 0.022   | -0.030 | -0.021 | 0.035  | 0.063  | -0.024 | 0.006  | -0.024 | -0.054 | 0.015  | -0.064 | 0.030  | 0.007  | 1.000  |        |        |
| Highereducation  | 0.081  | 0.022   | 0.048  | 0.012  | -0.002 | 0.020  | 0.031  | 0.052  | 0.051  | 0.071  | -0.007 | 0.026  | 0.076  | 0.093  | 0.000  | 1.000  |        |        |
| Riskyagegroup    | -0.009 | -0.032  | -0.027 | -0.043 | 0.026  | -0.019 | -0.025 | -0.003 | -0.049 | -0.036 | -0.050 | 0.093  | 0.013  | 0.020  | 0.037  | -0.095 | 1.000  |        |
