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Article

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Article

COVID-19 Vaccine Development in a Quadruple Helix Innovation System: Uncovering the Preferences of the Fourth Helix in the UAE

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Abstract: Successful development and uptake of vaccine technology in a Quadruple Helix Innovative health or economic system requires a clear understanding of society's preferences as the fourth helix. With significant financial commitments to find a safe and effective COVID-19 vaccine still ongoing, this study introduces a random utility theoretic behavioral health model to analyze individuals' prospective demand for the vaccine in the United Arab Emirates (UAE). To this end, we use a cross-sectional sample of stated vaccine preferences data collected online using the snowball method, between 4 July and 4 August 2020, gathering 1109 responses across all seven Emirates of the UAE. We found that in addition to socio-economic and demographic influences, the factors affecting individuals' preferences for the prospective COVID-19 vaccine in the UAE include those put forth by the WHO's SAGE group on immunization. Though the estimated indirect cost, in the form of expected marginal utility of time spent to get the vaccine is not statistically significant, the expected marginal utility of every dirham spent to get the vaccine is -1.76 AED and significant, suggesting a significant expected dis-utility from COVID-19 vaccine seeking/payment by the average person. Our findings also highlight significant perceived financial, temporal and spatial barriers to COVID-19 vaccine uptake in the UAE. Therefore, a set of measures are suggested to help mitigate the adverse effects of these three constraints. Our study thus contributes methodologically to the literature on vaccine demand, hesitancy and development. It also contributes to the nascent empirical evidence on the novel coronavirus disease, by providing significant insights for evidence based policy making that should increase the effectiveness of any prospective COVID-19 vaccination program in the UAE.

Keywords: biotechnology; coronavirus; COVID-19; innovation; vaccine demand; vaccine hesitancy

JEL Classification: I12; I18; C35; C51; C81; D91

1. Introduction

The use of medical biotechnology in vaccine research and development has long contributed to novel therapeutic solutions against infectious diseases [1,2], with vaccination perceived as one of public health's greatest achievements [3]. From the direct immune protective response of vaccinated individuals to the indirect community level protection through herd immunity, vaccination programs have contributed to safeguarding communities globally against the continued threat from numerous infectious diseases [4,5]. However, to successfully reduce the incidence and prevalence of a communicable disease, a high social vaccine uptake remains the most critical step [6,7].



Therefore, public trust in immunization has increasingly emerged to become an important and global health issue, as losses in vaccine confidence can lead individuals to delay or refuse vaccination, thereby risking the societal consequences of infectious diseases [8,9]. Despite the compelling evidence that vaccines have life saving values, "vaccine hesitancy", which is coined as "a delay in acceptance or refusal of vaccination despite availability of vaccination services", has grown to become a major public health concern [10–12]. The issue has been attributed to a host of factors evolving around access inconvenience, lack of confidence, and complacency, by the World Health Organization's (WHO) Strategic Advisory Group of Experts (SAGE) on immunization [13,14].

The recent emergence and global spread of the coronavirus pandemic has posed sizable threats to health and economic systems worldwide [15–17]. Though current responses to the pandemic involve harsh suppression strategies (including the identification of cases, followed by quarantine and isolation, in addition to contact tracing, and social distancing in public spaces), a working vaccine remains the most awaiting intervention globally [18–20]. In February 2020, consulting with the World Bank and other vaccine stakeholders, the Coalition for Epidemic Preparedness Innovations (CEPI) launched a COVID-19 Vaccine Development Taskforce, with the mission of financing, manufacturing, and distributing safe and effective COVID-19 vaccines globally [21]. As a global vaccine development funding mechanism, the CEPI is supported by a World Bank financial intermediary fund that pulls together private, public and philanthropic funding to address global priorities [22,23]. The investment required for the successful development of a least three COVID-19 vaccines was estimated by the CEPI at over 12 billion USD [21]. Much of which potentially funded through past innovative vaccines financing mechanisms, including the use of vaccine bonds by the International Finance Facility for Immunization (IFFIm), created to support the global vaccine alliance (Gavi) [24].

In the form of a Quadruple Helix innovation system [25–27], the ongoing development pathway for an effective COVID-19 vaccine is seeing the full collaboration of not only industry, government and academia, but also a synergy between biotechnology and pharmaceutical companies, to bring forward a variety of innovative vaccine technology platforms [28]. The current global COVID-19 R&D landscape include hundredth of vaccine candidates that rely on a wide range of vaccine technology platforms, including recombinant protein, virus-like particle, nucleic acid, viral vector, peptide, live attenuated and inactivated virus approaches [29–33]. Many vaccine candidates have now moved into clinical trials, including the mRNA-1273 from Moderna, the Ad5-nCoV from CanSino Biologicals, the INO-4800 from Inovio and the pathogen-specific aAPC from the Geno-Immune Medical Institute of Shenzhen [34]. Public data on COVID-19 vaccine development activities in Latin America and Africa are currently unavailable, however advanced developers of active candidates are reported from North America (46%), Europe (18%), China (18%), Asia and Australia excluding China (18%), collectively accounting for more than 25% of the world population [28]. National level initiatives also include the U.S. ACTIV (Accelerating COVID-19 Therapeutic Interventions and Vaccines) partnership between the private and public sectors [29].

Although such unprecedented efforts and investments in the development of an effective vaccine within the Quadruple Helix framework are to be saluted, the ability of any prospective vaccine to eradicate the pandemic will still depend on its acceptance and uptake by society as the fourth helix. That is, it will still have to pass the test of "vaccine hesitancy", which the WHO's SAGE working group identified as complex, context and vaccine specific, with spatial and temporal variations [13].

In the like of the rest of the world, the COVID-19 pandemic has also affected the United Arab Emirates (UAE). As of 29 October 2020 WHO's statistics show a total of 44,164,308 COVID-19 confirmed cases globally, with 30298756 full recoveries, and 1,169,525 casualties; in the specific case of the UAE, these figures were 130,336 confirmed cases, 126,147 full recoveries, and 488 casualties [35], respectively. The latest health statistics updates as of 31 October 2020, from the UAE Ministry of Health and Prevention live feed shows 13,040,169 total conducted tests since the beginning of the outbreak, with a daily average of 143,336 tests [36]. Total diagnosed positive cases amount to 131,508, of which 490 have passed away, 127607 have now fully recovered, and the remaining 3411 are still receiving care.

These figures suggest a COVID-19 positivity rate of 1.008%, for a fatality rate of 0.37%, and recovery rate of 97.03% in the UAE. Therefore, a national uptake of the prospective COVID-19 vaccine once available, would be important for eliminating the further threat from the SARS-CoV-2 [37,38].

To date however, scientific evidence of the general public's attitudes towards the prospective COVID-19 vaccine remains unavailable in the UAE. Nonetheless, numerous studies including in the UAE [39] have shown that individuals' decision-making concerning immunization are complex and multi-dimensional [11]. Instead of a dichotomous pro-vaccine versus anti-vaccine's perspectives, individuals' attitudes towards vaccines appear to be on a continuum that ranges from the lower end of complete vaccine refusal, to the upper end of complete vaccine acceptance [12,40]. Between these two extremes and along the continuum are varying degrees of vaccine-hesitancy [10,41]. Because of its potential to undermine the effectiveness of any national immunization program, understanding ahead of time its prevalence in society is key to the success of any national strategy against the COVID-19 pandemic. Existing studies on the issue of COVID-19 vaccine hesitancy in the United States [42] and Saudi Arabia [43] report on key determinants based on alternate less comprehensive frameworks.

As a behavioral outcome of a decision process with greater complexity, vaccine hesitancy is affected by a wide range of factors. On March 2012, the WHO's SAGE group on immunization developed a matrix of its determinants informed by the expertise of group members, and a systematic review of peer reviewed publications. The matrix mapped contextual, individual and group, and vaccine-specific factors, as the key determinants of the decision to accept, delay or reject vaccines [14]. The menu of survey questions used in our current study is framed based on the WHO's SAGE group matrix, to allow for the diagnosis and addressing of potential hesitancy towards the prospective COVID-19 vaccine in the UAE. Although applied to COVID-19 vaccine demand in the specific context of the UAE's adult population aged 18 and above, the study is designed to provide a holistic framework for vaccine demand analysis that combines three key paradigms in the scientific literature: the technology acceptance model (TAM), the framework on vaccine skepticism, and Random Utility Theory. The resulting framework is a tripartite model that jointly addresses three fundamental questions related to vaccination in general, and COVID-19 vaccination in particular:

- What are the determinants and the extent of COVID-19 vaccine acceptance in the UAE?
- How much time are individuals willing to spend to get the COVID-19 vaccine in the UAE?
- How much money are individuals willing to pay for the COVID-19 vaccine in the UAE?

In what follows, we now provide a brief review of the literature on vaccine demand (acceptance/hesitancy/refusal) in Section 2, followed by a presentation of the data collection procedure in Section 3, then in Section 4 we present our proposed analytical framework for vaccine preference analysis, while in Section 5 we present and discuss our findings, and finally in Section 6 we conclude the analysis.

2. The Literature Review and Conceptual Framework

Originally conceptualized by Elias Carayannis and David Campbell, as a spiral with four strands, the Quadruple Helix model of innovation recognizes (H1:) Academia, (H2:) Industry, (H3:) Government and (H4:) Society (or the public) as the four major actors in innovation systems [27]. The main constituent of this helical system being knowledge, which flows among the four helices to foster environmentally friendly economic and social development [26]. The functional role of the fourth helix in this framework has grown fundamental for many technological artifacts, including vaccine technology [25]. In this latter case, society's participation is not only required for vaccine development through human trials of vaccine candidates to ensure safety and efficacy [44,45]; society's general uptake of the successful vaccine, once available, is also required to ensure the effective eradication of the vaccine preventable disease [46]. Therefore a non-cooperating fourth helix in the form of hesitancy and/or refusal could potentially undermine vaccine development, and effectiveness [47,48].

Although reflecting a specific subset of the general vaccine demand spectrum [40], "Vaccine hesitancy" is reported to be the root cause of reduced vaccine coverage in society, and the increased prevalence of infectious disease outbreaks [49]. Some of the earlier comprehensive address of the issue in the literature include the review by [50], which provides possible explanations for its apparent increased prevalence in the developed world. The review conjointly identifies a number of determinant factors of individual decision-making about vaccination including: vaccine knowledge; past vaccination service experiences; perceived vaccine health benefits; complementary and/or alternative medical recommendations from health professionals; perceived risks; trust; personal norm; pressure from and responsibility towards society; religious and moral convictions. Building on the recognition of the global significance of vaccine hesitancy, and after interviewing immunization managers (IMs) in 13 countries, [51] found inconsistent definitions of the concept of vaccine hesitancy, which they report to be influenced by factors such as convenience, complacency and confidence. Moreover, they found heterogeneous and context-specific causes of vaccine hesitancy across the different countries, suggesting the importance of customized strategies for individual national immunization program's strengthening, based on locally identified relevant causal factors.

In a follow up analysis, [49] shed lights on the contribution of anti-vaccination movements in fueling the growth in vaccine hesitancy, and thereby lowering vaccine acceptance rates and increasing vaccine-preventable disease outbreaks. Further, following the formalization of vaccine hesitancy definition as "delay in acceptance or refusal of vaccination despite availability of vaccination services", [13] presented a matrix categorizing vaccines determinants into three major groups: personal and peer, contextual, and vaccine specific influences. Relying on this matrix, [14] proposed the development of a survey questionnaire for measuring and addressing hesitancy in various settings. In doing so, the authors reorganized the initially identified factors in [50] into the three categories of the determinant matrix in [13], through the proposition of a set of questions that capture each dimension of the matrix. Since then, the framework has been used to diagnose the determinants of vaccine hesitancy in specific settings, including population subgroups [52], therefore assisting public health officials tailor national immunization programs for more effectiveness [53,54].

Because of the key role health professionals play in providing and helping the general public understand the value of health services, including preventive medicine, their own perception of vaccines inevitably influence how they influence the general public's perception. Focusing therefore on a cross-sectional observational study of 1712 General Practionners (GPs) in France, [55] investigated vaccine hesitancy and its determinants during controversies. They found that vaccine hesitancy became more prevalent among French GPs, whose vaccine recommendation decisions varied based on their own trust in public authorities, perceived vaccine risks and utility, in addition to their comfort level in justifying those recommendations.

In a more comprehensive study to provide a global insight through a survey run in 67 countries, [8] reported on the state of vaccine confidence as of 2016. Their findings revealed an overall positive sentiment towards vaccination across the 67 countries, though significant heterogeneity were found between countries and across world regions. Adverse vaccine-safety sentiments appeared more prevalent in Europe, where 7 of the 10 least confident nations in the study were located. Favorable views were recorded among the 65 and over age group, and Roman Catholics, however religion based vaccines incompatibility was the highest in the Western Pacific region. Overall, countries with the lowest rates of positive vaccines sentiments were characterized by good access to health services and high levels of schooling, pointing out a global emergence of an inverse relationship between socio-economic status and vaccine sentiments.

Moreover, the findings reported by [56], within the specific context of the United States, show that in addition to emotion, culture and religion, the socio-political context significantly shape attitudes about vaccination. Indeed, relying on a nationally representative internet survey of 1006 U.S. respondents, the study considered the impact of political ideology and trust on public opinions about flu, pertussis, and measles vaccinations. The results showed both an indirect effect of political ideology on immunization propensity depending on individual's trust in government and medical experts; and a direct effect of political ideology on vaccine attitudes, with conservatives being less prone to express pro-vaccines sentiments than other individuals.

Understanding therefore the complexity of the issue of vaccine hesitancy, and the risk communication challenges it poses, [57] describe good practices in developing public health communications that are sensitive to the complex ways in which people process and value information, and thus more likely to optimize community level vaccine uptake. These were summarized as (i) establishing trust, (ii) describing both the benefits as well as the risks of the vaccine, (iii) giving the facts prior to discussing the myths, (iv) using visual imagery, and finally (v) testing the communication material prior to launching.

Within the specific context of the United Arab Emirates (UAE), using an Arabic version of "The Parent Attitudes about Childhood Vaccines (PACV) survey", a generally accepted tool for studying parental vaccine hesitancy behavior in its English version, [39] studied the reliability of the transcribed survey tool, along with assessing the general prevalence of vaccine hesitancy among UAE parents. Their findings revealed a 0.79 Cronbach alpha score for the Arabic-PACV, suggesting its reliability for evaluating vaccine hesitancy in native Arabic-speaking health systems. Moreover, only 12% of study participants were reported hesitant, with safety and side effects, reported as the main concerns for hesitancy.

Though the above discussion describes a vast literature on vaccine hesitancy in general, the literature on COVID-19 vaccine hesitancy in particular remains very limited due to the novel nature of the pandemic. Nevertheless, In the United States, [42] addresses COVID-19 vaccine hesitancy and its implications for herd immunity, using a randomized control trial of 3133 participants. Their findings revealed that 20% of Americans intend to decline the COVID-19 vaccine, with distrust of vaccine safety and vaccine novelty being amongst the most important deterrents to vaccine uptake. Contributing also to the reported vaccine hesitancy was the lack of consistency between the messages from public health experts and the government.

Similarly in Saudi Arabia, [43] reports on the determinants of COVID-19 vaccine acceptance using a web-based national survey of 1000 invitees, of which 992 responded. Their findings revealed that 642 (or 64.72%) of Saudis show interest in accepting the prospective vaccine. Acceptance is reported to be high among individuals 45 and older (79.2%), non-Saudi (69.1%), married (69.3%), with at least postgraduate degree (68.8%), and working in the public sector (68.9%). The odds of vaccine acceptance were also reported higher among people trusting the Saudi health care system, and those with higher perceived risk of getting infected.

To date however, no study reports on the topic of COVID-19 vaccine demand within the specific context of the UAE, therefore understanding the behavioral and context specific nature of vaccine demand/hesitancy as above described, this paper introduces a random utility based framework of vaccine preference analysis (see Figure 1), which is subsequently used to study vaccine demand behavior in the UAE.



Figure 1. Random Utility Based Conceptual Framework for Individual's COVID-19 vaccine decision-making. It is adapted from Figure 2 in [58].

3. The Data

Our study relies on a cross-sectional data set of 1109 respondents aged 18 and above, and living in the UAE. The data coverage includes all seven emirates of the UAE (i.e., Abu Dhabi, Ajman, Dubai, Fujairah, Sharjah, Ras Al Khaimah, Umm al Quwain), and was collected online between 4 July and 4 August 2020, using the snowball sampling strategy. For the reader interested in more elaborate details, the data is openly available at [59], with the full account of its sampling design, material and methods described in the published peer-reviewed open access data article [58]. The fully anonymized version of the data was used for all analyses and interpretations. Descriptive statistics were also conducted to generate summary tables of study variables. Chi-square tests with cross tabulation analyses were performed to examine the dependence between COVID-19 vaccine demand outcome variables and their identified determinants as shown in Figure 1. The Random Utility model as described below, with its probit and logit specifications were used for data modeling. All data analyses were performed using the R statistical software.

4. Random Utility Model of Stated (COVID-19) Vaccine Preferences

The random utility model of stated vaccine preferences analysis developed in this section is an extension of the framework presented in [16], which follows Daniel McFadden's utility interpretation [60]. The current model assumes that an individual decision about (COVID-19) vaccine (refusal, hesitancy, acceptance) is a reflection of the utility (s)he derives from vaccine based immunization. The lower the subjectively perceive utility from vaccine based immunization, the more hesitant the individual, and the higher the perceived utility the less hesitant and thus more accepting is the individual. Because of the subjective nature of this utility to the individual decision maker, it is inherently unknown (thus random) to the researcher. As such, in its additive random utility (ARUM) framing, the total utility the individual derives from vaccine based immunization is the sum of an observed (non-random) utility component, and an unobserved (random) utility component. The observed component of this utility is assumed to be an indirect differentiable continuous and endogenous function of the individual's willingness to spend time and money to get vaccinated (see observed determinants in orange, Figure 1), but an exogenous function of her socio-economic and demographic characteristics, along with the WHO's SAGE working group identified vaccine demand determinants (see observed determinants in green, Figure 1) [13,14].

Furthermore, in an economic system where resources have to be pulled together to produce a good (in this case a vaccine), it is reasonable to assume resource owners (investors) would like to recover their investment, if not have a return on their investment. Therefore, we assume the existence of a market for COVID-19 vaccine, where vaccine producers meet and trade with potential and actual vaccine consumers. Standard micro-economic theory would suggest that the demand for a vaccine by an individual consumer, would depend on her/his willingness and ability to pay (directly and/or indirectly) for the vaccine, as a health good. Thus, the above described Random Utility Model can be expressed mathematically as a joint system of three equations: (i) the vaccine preference outcome equation (with varying degrees of acceptances), (ii) the opportunity cost equation (amount of time willing to spend to get the vaccine), and (iii) the direct cost equation (amount of money willing to spend for the vaccine).

The vaccine preference continuum in the first equation is captured by the answer to the question "How willing would you be, to get the COVID-19 vaccine once discovered?", with potential outcomes of "vaccine refusal" if chosen option is (0—not at all); "vaccine hesitant" if chosen option is (1—a little; or 2—moderate amount); "vaccine acceptant" if chosen option is (3—quite a bit). As the stated opportunity cost of vaccination in the second equation, the time the individual is willing to spend to get the vaccine is captured by the answer to the question "What is the maximum amount of time (in minutes) you would be willing to spend to get the COVID-19 vaccine, once discovered?", with six ordered outcomes (0—none; 1—less than 30 min; 2—30 to 60 min; 3—60 to 90 min; 4—90 to 120 min; 5—over 120 min). On the other hand, the stated direct financial cost of vaccination in the third equation, is the outcome of the question "What is the maximum amount (in dirham), that you would be willing to pay for the COVID-19 vaccine, once discovered?". It has seven potential choice options (0—0 AED; 1—less than 100 AED; 2—100 to 200 AED; 3—200 to 300 AED; 4—300 to 400 AED; 5—400 to 500 AED; 6—over 500 AED).

Since the resulting Random Utility model is a trivariate system of linear equations with qualitative ordinal responses, we rely on multivariate ordinal regression modeling, which is an appropriate choice modeling framework for a vector of correlated ordinal responses observed together with covariates, for a random sample of respondents [61].

4.1. Multivariate Ordinal Regression Model (MVORM) Specification

In the general representation of the MVORM, we let Y_{ij} denote the multivariate ordinal response, and x_{ij} be the *p* dimensional vector of explanatory factors for individual *i* and vaccine outcome *j*, with i = 1, ..., n and $j \in J_i$, where J_i is a realized subset from the full outcome space *J* in the studied sample. Furthermore, denoting the number of sample space outcomes in J_i and *J*, by $q_i = |J_i|$ and q = |J|, respectively, while relying on the cumulative link function approach to model the relationship between the multivariate ordinal vaccine outcome Y_{ij} and the latent utility U_{ij} individuals' derive from vaccine uptake, we get:

$$Y_{ij} = r_{ij} \iff \theta_{j,r_{ii}-1} < U_{ij} \le \theta_{j,r_{ii}}, \ r_{ij} \in \{1,\dots,K_j\},\tag{1}$$

where r_{ij} is a choice alternative out of K_j ordered alternatives, and θ_j are the corresponding unknown cutoff points, for vaccine outcome j, and abiding to the following conditions: $-\infty \equiv \theta_{j,0} < \theta_{j,1} < \ldots < \theta_{j,K_{j-1}} < \theta_{j,K_j} \equiv +\infty$. In our current application with three ordinal response variables, j = 1, 2, 3 such that $K_1 = 4, K_2 = 6$, and $K_3 = 7$. Using the additive random utility (ARUM) framing as above described, the multivariate random utility function U_{ij} is given by:

$$U_{ij} = \beta_{j0} + x_{ij}^1 \beta_j + \epsilon_{ij}, \quad \forall i = 1, \dots, 1109 \quad and \quad j = 1, 2, 3.$$
(2)

Or more explicitly

$$U_{i1} = \beta_{10} + x_{i1}^{T}\beta_{1} + \epsilon_{i1},$$

$$U_{i2} = \beta_{20} + x_{i2}^{T}\beta_{2} + \epsilon_{i2},$$

$$U_{i3} = \beta_{30} + x_{i3}^{T}\beta_{3} + \epsilon_{i3}$$
(3)

where, x_{ij} are the explanatory factors, and based on our conceptual framework in Figure 1 $x_{ij}^T \beta_j$ is the observable part of the utility function, with the following explicit form:

$$\begin{split} x_{ij}^{T}\beta_{j} &= \beta_{j1}*Age + \beta_{j2}*Gender + \beta_{j3}*MariStat + \beta_{j4}*Nationality + \beta_{j5}*Education \\ &+ \beta_{j6}*Occupation + \beta_{j7}*IncomeMonthly + \beta_{j8}*Reside + \beta_{j9}*KnowVaccine \\ &+ \beta_{j10}*EnouInfVacSafty + \beta_{j11}*EverNOTvaccin + \beta_{j12}*Any1BadReactVac \\ &+ \beta_{j13}*ImportnCoVacEvery1 + \beta_{j14}*NoVaccRelgCult + \beta_{j15}*RiskngHlth \\ &+ \beta_{j16}*InfoSrceCov + \beta_{j17}*ImportnCoVacc + \beta_{j18}*ConcernCoVacc \\ &+ \beta_{j19}*CoVaccPrefAdmnMod + \beta_{j20}*FinCostCoVacPrevGet \\ &+ \beta_{j21}*TravelOver1HrCoVacc + \beta_{j22}*TravelDiffEmirCoVacc \end{split}$$

while ϵ_{ij} is the unobservable part of utility, and also described in Figure 1. Moreover, $\beta_{j0} = (\beta_{10}, \beta_{20}, \beta_{30})^T$ represents the vector of intercept terms, while $\beta_j = (\beta_{j1}, \dots, \beta_{j22})^T$ is the vector of coefficients, capturing the effects of the observed determinants.

Distributional assumptions about the error terms $\epsilon_{ij} = (\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3})$, yield different behavioral models that account for the dependence across the three responses variables for each respondent *i* in the sample. For example the logit model, results from the assumption that ϵ_{ij} follows a multivariate logistic distribution, with a *t* copula binding the univariate logistic margins, with *v* degrees of freedom [61]. The probit model on the other hand results from assuming the ϵ_{ij} to be jointly normally distributed; that is, $\epsilon_i = |\epsilon_{ij}|_{i=1,2,3} \sim N_{q_i}(\mathbf{0}, \mathbf{\Sigma}_i)$.

In terms of identification, the absolute values of both the scale and location parameters are not identifiable in discrete ordinal models. Assuming the covariance matrix to be Σ_i , with diagonal elements $|\sigma_{ij}^2|_{j \in J_i}$, only the quantities β_j / σ_{ij} and $(\theta_{j,r_{ij}}\beta_{j0})/\sigma_{ij}$ are identifiable in Equation (1). Therefore, further restrictions on the parameter space are typically required to obtain an identifiable model. We achieve this in our current application by leaving the intercept terms β_{10} , β_{20} and β_{30} unrestricted, but fixing the first threshold parameter in each of the three outcomes (i.e., $\theta_{1,1} = \theta_{2,1} = \theta_{3,1} = 0$), while leaving the σ_{ij} unrestricted for all j = 1, 2, 3. We further represent the dependence between the three outcome variables by assuming pairwise heterogeneous correlation parameters across the three outcomes, such that $Corr(\epsilon ik, \epsilon il) = \rho kl$, and a constant variance across all individuals, for each outcome (i.e., $VAR(\epsilon_{ij}) = \sigma_i^2$, $\forall j = 1, 2, 3$), as commonly used the literature [62].

4.2. Composite Likelihood Estimation

We rely on a composite likelihood approach to estimate the parameters of the model. To this end, we approximate the complete likelihood function with pseudo-likelihood functions, built from lower dimensional marginal density functions, through aggregation of corresponding pairs of observations [63]. The likelihood of observing the δ parameter vector of regression coefficients, along with the threshold and error structure parameters is given by:

$$\boldsymbol{\ell}(\boldsymbol{\delta}) = \prod_{i=1}^{n} P\left(\bigcap_{j \in J_i} \{Y_{ij} = r_{ij}\}\right)^{w_i} = \prod_{i=1}^{n} \left(\int_{D_i} f_{i,q_i}(\mathbf{U}_i; \boldsymbol{\delta}) d^{q_i} \mathbf{U}_i\right)^{w_i},\tag{4}$$

where w_i are non-negative probability weights specific to each individual, and all equal to 1 in a random sample of equally likely respondents; f_{i,q_i} is the q_i -dimensional (here three dimensional) density of the error terms $\epsilon_i = (\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3})$; and $D_i = \prod_{j \in J_i} (\theta_{j,r_{ij}-1}, \theta_{j,r_{ij}})$ is a Cartesian product. This complete likelihood function in Equation (4) is approximated by the following pairwise pseudo-likelihood function [64], constructed from lower dimensional bivariate marginal density functions:

$$p\ell(\delta) = \sum_{i=1}^{n} w_i \left[\mathbbm{1}_{\{q_i \ge 2\}} \sum_{(k < l) \in J_i} \log(P(Y_{ik} = r_{ik}, Y_{il} = r_{il})) + \mathbbm{1}_{\{q_i = 1\}} \mathbbm{1}_{\{k \in J_i\}} \log(P(Y_{ik} = r_{ik})) \right]$$
(5)

Letting the uni-variate and bivariate density functions corresponding to the error distribution be denoted by $f_{i,1}$ and $f_{i,2}$ respectively, then their corresponding probabilities are given by:

$$P(Y_{ik} = r_{ik}, Y_{il} = r_{il}) = \int_{\theta_{k,r_{ik}-1}}^{\theta_{k,r_{ik}}} \int_{\theta_{l,r_{il}-1}}^{\theta_{l,r_{il}}} f_{i,2}(U_{ik}, U_{il}; \delta) dU_{ik} dU_{il},$$

$$P(Y_{ik} = r_{ik})) = \int_{\theta_{k,r_{ik}}}^{\theta_{k,r_{ik}}} f_{i,1}(U_{ik}; \delta) dU_{ik}.$$
(6)

The direct maximization of the function in Equation (5) yields the estimated pairwise maximum likelihood values of the parameters $\hat{\delta}_{p\ell}$ [65]. Asymptotically, the maximum pairwise likelihood estimator is normally distributed with asymptotic mean $\delta_p \ell$, and asymptotic covariance matrix $G(\delta)^{-1}$ such that:

$$G(\delta)^{-1} = H(\delta)^{-1}V(\delta)H(\delta)^{-1},$$

where $G(\delta)^{-1}$ is the inverse of the Godambe information matrix [66], $H(\delta)$ is the Hessian matrix, while $V(\delta)$ is the variability matrix; both of which are estimated as:

$$\hat{H}(\delta) = -\frac{1}{n} \sum_{i=1}^{n} \left(\frac{\partial^2 p \ell_i(\hat{\delta}_{p\ell})}{\partial \delta \partial \delta^T} \right) = \frac{1}{n} \sum_{i=1}^{n} \sum_{(k$$

and

$$\hat{V}(\delta) = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{\partial p \ell_i(\hat{\delta}_{p\ell})}{\partial \delta} \right) \left(\frac{\partial p \ell_i(\hat{\delta}_{p\ell})}{\partial \delta} \right)^T$$

with $p\ell_i(\delta)$ corresponding to the pairwise log-likelihood component for individual *i*; and $p\ell_{ikl}(\delta)$ corresponding to individual *i* and pair (k, l). Contrasting the performance of different behavioral models such as that of the probit, and logit specifications is achieved here using the composite likelihood information criterion: $CLIC(\delta) = -2p\ell(\hat{\delta}_{p\ell}) + k tr(\hat{V}(\delta)\hat{H}(\delta)^{-1})$. In this representation the Akaike (CLA) and Bayesian (CLB) information criterion are obtained as (CLAIC) and (CLBIC) respectively by setting k = 2, and $k = \log(n)$ [67]. Estimation of the above described multivariate ordinal regression model is achieved using the *MMO2* function from the "mvord" package [68] within the R statistical software [69].

5. Results

The results are organized in two subsections, the first of which provides summary statistics describing the variables, while the second presents the results of the Pairwise Maximum Composite Likelihood estimation of the multivariate ordinal regression model (MVORM).

5.1. Descriptive Findings

The descriptive findings are also organized into univariate descriptive statistics, and bivariate (Chi-squared based) descriptive statistics.

5.1.1. Univariate Descriptive Statistics

Tables A1–A4 summarize the univariate descriptive findings, in the form of frequency, and relative percent frequency distributions. Starting with the COVID-19 vaccine outcome variables in Table A1, it can be noted from individuals' willingness to get the COVID-19 vaccine (WTGCoVacc) in the upper portion of the table that "vaccine refusal" (0—Not all all) characterizes 25.16% of study participants, while "vaccine acceptance" (3-Quite a bit) is observed for 22.09% of the respondents. Between these two extremes is "vaccine hesitancy" which characterizes the COVID-19 vaccine preference of 52.75% of respondents, with low hesitancy (2—A moderate amount) representing 32.10%, and high hesitancy (1—A little) representing 20.65%. With respect to the maximum time (in minutes) individuals are willing to spend to get the prospective COVID-19 vaccine (MaxTimWillgSpndCoVacc), it can be noted from Table A1 that 5.68% of the respondents are unwilling to spend any time to get the vaccine once available, the greater majority however (46.17%) are willing to spend at most 30 min to get vaccinated, 8.57% are willing to spend between 30 to 60 min, 5.14% are willing to spend between 60 to 90 min, 21.82% are willing to spend between 90 to 120 min, and finally 12.62% are willing to spend over 120 min to get the COVID-19 vaccine. With regards to the maximum amount of money (in dirham) that individuals are willing to spend to get the prospective COVID-19 vaccine (MaxWTPCoVacc), Table A1 shows that 25.61% of the respondents are unwilling to spend any money to get the vaccine once available. The greater majority of study participants however (40.04%) are willing to spend at most 100 AED, while 13.17% are willing to spend between 100 and 200 AED, 7.84% are willing to spend between 200 and 300 AED, 2.80% are willing to spend between 300 and 400 AED, 4.60% are willing to spend between 400 and 500 AED, and finally 5.95% are willing to spend over 500 AED to get the COVID-19 vaccine.

Turning now our attention to the economic and socio-demographic factors in Table A2, we note that the majority of study participants are females (72.14%), married (77.55%), non-Emirates (77.82%), and living in Abu Dhabi (71.78%). 11.63% live in the Emirate of Dubai, and 16.59% reside in one of the other five remaining emirates. In terms of respondents' age, most (39.40%) are in the 36 to 45 years age category, followed by 27.95% in the 26 to 35 years category, then by 19.75% in the above 45 years age category, then by 12.89% in the 18 to 25 years category. With regards to education, most respondents (59.06%) report to having a graduate degree, followed by 15.60% with a postgraduate degree, then by 14.07% having at most a high school degree, and 11.27% having a two year diploma. In terms of respondents' occupation, 35.17% report to being self-employed or employed in the private sector, 34.99% report to not-working, while 29.84% report to working for a governmental or semi-governmental agency. The monthly income figures suggest that most respondents (31.2%) have monthly earnings below 10,000 AED; followed by 24.8% reporting a monthly income between 10,000 and 20,000 AED; then by 16.59% reporting a monthly income between 20,000 and 30,000 AED, then by 14.16% reporting earning above 30,000 AED. The lowest majority of respondents however (13.44%) report to having no monthly income.

Table A3 also summarizes the personal and peer influences on respondents' perceived COVID-19 vaccine utility; the factors characterizing vaccine knowledge and information show that 631 (56.90%) of respondents report to knowing what a vaccine is, while 459 (41.39%) report to getting enough information on vaccines and their safety. On the factors characterizing respondents' past experiences with vaccines, 275 (24.80%) report to have refused a vaccination in the past, while 233 (21.01%) report to knowing someone who has had a bad reaction to a vaccine in the past. On the perceived subjective norm of COVID-19 vaccination, Table A3 shows that the greatest majority of the respondents (59.96%) believe it is highly important for everyone to get the vaccine once available, 20.92% show a moderate belief in the importance of COVID-19 vaccine for everyone, 8.93% show a low belief, while 10.19% believe it is not at all important for everyone to get the vaccine once available. Based on religious and moral grounds, only 124 (11.27%) report to knowing someone that does not accept vaccines because of religious or cultural convictions, with 724 (65.37%) reporting such convictions based refusal to pose a great health risk for vaccine refuters and their families.

The contextual and COVID-19 vaccine specific factors influencing respondents' perceived COVID-19 vaccine utility are summarized in Table A4. It can be noted from the table that 484 (43.64%) of the respondents get their information on COVID-19 from general internet search, 373 (33.63%) from UAE government's website, and the remaining 252 (22.72%) from other sources of information including news papers, radio, television. On the perception of COVID-19 vaccine's importance, the greatest majority of respondents 671 (60.50%) believe the vaccine is very important, 244 (22%) believe it is moderately important, 88 (7.94%) believe it is a little important, and finally 106(9.56%) believe that the vaccine is not important at all. With respect to individuals' concerns about the COVID-19 vaccine, most respondents 455 (41.03%) report to being highly concerned, 394 (35.53) report to being moderately concerned, 160 (14.43%) report to being a little concerned, and finally 106 (9.56%) report to not being concerned at all. In regards to respondents' preferred mode of COVID-19 vaccine administration, the majority 488 (44%) prefer injections, 310 (27.95%) prefer oral administration, 72 (6.49%) prefer nasal sprays, while 239 (21.55%) report none of the administration modes to be of their preference. On respondents' perceived barriers to COVID-19 vaccine uptake, 577 (52.03%) report that the financial cost of the prospective COVID-19 vaccine could prevent them from getting it, if it is not freely offered; on the time constraint to the COVID-19 vaccine uptake, 366 (33%) of respondents report that they would not consider it important enough to travel over an hour to get the vaccine. Finally on the spatial constraint to the COVID-19 vaccine uptake, 403 (36.34%) report to being unwilling to travel to a different Emirate to get the vaccine if it was not readily available in their immediate Emirate of residence.

5.1.2. Bivariate Descriptive Statistics with Chi-Squared Tests Results

As summarized in Table A5, the bivariate descriptive findings are intended to statistically ascertain the assumed theoretical relationships presented in the conceptual framework (see Figure 1), between the COVID-19 vaccine outcome variables and the explanatory factors. The dependence results with the vaccine preference indicator are shown in the first column of the table under "WTGCoVacc", with the chi-squared test statistics (Stat), degrees of freedom (df), and corresponding p-values appearing to validate the overall significance of the framework. Indeed, at the exception marital status, occupation, vaccine knowledge, and information source on COVID-19 vaccine, all remaining identified factors in the framework show a statistically significant dependence based on their p-values, which are less than or equal to the 5% significance level.

A similar observation is made with the second dependent variable (MaxTimWillgSpndCoVacc) in the second column of Table A5. Indeed, based on the p-values of the chi-squared test of dependence, only the factor capturing respondents' reported perception about getting enough information on vaccines and their safety, and the factor characterizing the influences of respondents religious and moral convictions, appear to not significantly influence the maximum time (in minutes) individuals are willing to spend to get the prospective COVID-19 vaccine. All remaining factors identified in the framework (see Figure 1) show a significant dependence with this latter outcome.

Finally, as shown in the third column of Table A5, at the exception of place of residence and vaccine knowledge, the chi-squared test results suggest a significant dependence between the maximum amount of money respondents are willing to pay for the COVID-19 vaccine (MaxWTPCoVacc), and the explanatory factors identified by the conceptual framework in Figure 1.

5.2. Econometric Results

For sensitivity and comparative model performance analysis, we have estimated both the multivariate ordered probit and multivariate ordered logit specifications of our Econometric model described in Section 4.1. Table A6 shows the performance indicators from the estimations of the two model specifications. Based on both, the Akaike (CLAIC) and Bayesian (CLBIC) composite likelihood information criteria, the multivariate logit model appears to have a relatively better performance. Indeed its CLAIC value of 16,345.22 is lower than that of the probit specification at

16,346.81; and similarly for its CLBIC =17,444.64, which is also lower than that of the probit specification at 17,445.57. Therefore, we choose the multivariate logit model as our preferred specification, the results of which are summarized in Table A7, and presented in the next sub-section.

Recall however from the discussions in Section 4.1 that we achieved identification in our current application by leaving the intercept terms β_{10} , β_{20} and β_{30} unrestricted, while fixing the first threshold parameter in each of the three outcomes (i.e., $\theta_{1,1} = \theta_{2,1} = \theta_{3,1} = 0$). As the results in the upper part of Table A6 show, all estimated threshold parameters/cutoff points (for the first outcome variable $\theta_{1,2} = 0.909, \theta_{1,3} = 2.171; \theta_{2,2} = 2.186, \theta_{2,3} = 2.447, \theta_{2,4} = 2.603, \theta_{2,5} = 3.460; \theta_{3,2} = 1.480, \theta_{3,3} = 1.987, \theta_{3,4} = 2.374, \theta_{3,5} = 2.548, \theta_{3,6} = 2.933$) are statistically significant at an alpha of 0.1%.

Moreover, the estimated intercept terms in Table A6 show that $\beta_{10} = -2.131$ and $\beta_{30} = -1.760$ are statistically significant, while $\beta_{20} = -0.132$ is not. The implications of these negative intercept values are that irrespective of any influencing factors, the expected process of acquiring the COVID-19 vaccine based immunization is associated with a dis-utility for the average individual. More specifically, $\beta_{10} = -2.131$, suggests an expected 2.131 increased dis-utility along the vaccine continuum, for the average individual seeking the COVID-19 vaccine. Similarly, $\beta_{30} = -1.760$ suggests an average expected 176 AED increased dis-utility for every 100 AED increased spending to get the COVID-19 vaccine. Though the results also point out a dis-utility from the time spent getting the vaccine ($\beta_{20} = -0.132$), this opportunity cost driven dis-utility is not statistically significant. These results seem to suggest that all things being equal, the average individual would have rather preferred not to deal with the novel coronavirus disease, and the need to protect oneself from it, through vaccination. A finding quite natural, given that by its very nature a "dis"- "ease" of any kind, including that brought by the SARS-CoV-2 virus is always utility depleting, while vaccine based immunization is, at least theoretically utility improving. Individuals' perceptions of the interplay of these two utility forces, eventually shape their subjective preferences for the vaccines.

5.2.1. The Endogeneity Test for Time and Money Willing to Spend for COVID-19 Vaccine

Recall from the discussions of our random utility model of stated vaccine preferences analysis developed in Section 4, that the observed component part of COVID-19 vaccine utility is assumed to be an indirect differentiable continuous and endogenous function of individuals' willingness to spend time and money to get vaccinated [See observed determinants in orange, Figure 1], but an exogenous function of the remaining identified vaccine demand determinants [See observed determinants in green, Figure 1].

This endogeneity assumption has led to the joint modeling of the three processes in an endogeneity switching regression framework [70], to allow for the potential correlations between their generated error terms $\epsilon_i = (\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3})$, in order to avoid potential biases from not accounting for such correlations. Testing for the validity of this assumption post-estimation, is achieved by evaluating the statistical significance of the estimated correlation coefficients [71]. As shown in the bottom part of Table A6, all three coefficients $Corr(\epsilon_{i1}, \epsilon_{i2}) = 0.212$; $Corr(\epsilon_{i1}, \epsilon_{i3}) = 0.430$; and $Corr(\epsilon_{i2}, \epsilon_{i3}) = 0.365$ are indeed statistically significant at an alpha of 0.1%, suggesting that the unobserved factors affecting individuals' reported COVID-19 vaccine preferences, depend significantly on those influencing their willingness to spend time, and those influencing their willingness to spend money to get the COVID-19 vaccine. Thus, validating our hypothesized endogeneity of these latter two determinant factors of COVID-19 vaccine preference.

5.2.2. The Impact of Economic and Socio-Demographic Influences

Though age significantly affect individuals' willingness to get the COVID-19 vaccine (-0.163); it does not appear to significantly influence the maximum time, nor money they are willing to spend for their chosen vaccine preferences. Indeed, aging appears to be a significant contributing factor of COVID-19 vaccine hesitancy, since expected utility appears to decrease by 16.3%, across each increasing

age category. In addition, no significant gender based differences exist in individuals' COVID-19 vaccine preferences in the UAE.

Though no significant difference exist also between married and unmarried individuals in their willingness to get the COVID-19 vaccine, nor the maximum amount of time they are willing to spend on this process, our findings show however that married individuals are relatively less willing to spend money to get the COVID-19 vaccine. Indeed, the expected utility from every 100 AED increased spending on COVID-19 vaccine is 61.7% lower for married individuals, compared to their unmarried counterparts. This finding seems to suggest that perhaps relatively speaking married individuals have greater subjectively perceived total out-of-pocket immunization expense requirements for the whole family, which leads them to prefer a lower family per-capita prospective cost of COVID-19 immunization. In other words, because unmarried individuals may perhaps just have to pay for themselves alone, their expected lower budgetary burden of COVID-19 immunization leads them to have a higher individual willingness to pay for the COVID-19 vaccine.

The estimated effects of nationality show a significant difference in COVID-19 vaccine preferences between locals and non-locals of the UAE. In fact, non-locals appear to exhibit more COVID-19 vaccine hesitancy (less willingness to get the vaccine), with an expected relative dis-utility of 68.2% from COVID-19 vaccine uptake, than to their local counterparts. However, non-locals show relatively 41.7% higher expected utility from every 30 min increase in the time spent acquiring the COVID-19 vaccine, but a 50.1% lower expected utility from every 100 AED increase spending on the COVID-19 vaccine. These findings suggest that compared to their local counterparts, non-locals are relatively more willing to spend their time, but less willing to spend their money to get the COVID-19 vaccine. Economically, these results seem to further suggest that UAE locals have a relatively higher perceived opportunity cost of their time than non-locals, while non-locals have a relatively higher perceived opportunity cost of their money than their local counterparts.

Education seems to have varying effects on individuals' preferences for COVID-19 vaccine in the UAE. In fact, no significant difference in COVID-19 vaccine preferences (willingness to get the vaccine) exist between those with at most a high school degree, and those with a two year diploma. However, individuals with a graduate degree are seen to exhibit significantly more vaccine confidence, and more willingness to pay for the COVID-19 vaccine, than their counterparts with at most a high school degree. Indeed, the results show a relative 37.1% higher expected utility from COVID-19 vaccine uptake for individuals with a graduate degree, and a relative 39.8% higher expected utility from every 100 AED increase spending on the vaccine. Taking into account the estimated results for individuals with a post-graduate degree, our findings seem to suggest that increased levels of education lead to stronger preferences for COVID-19 vaccine immunization in the UAE. Indeed, we find that compared to individuals with at most a high school degree, those with a postgraduate degree have 45.5% higher expected utility from COVID-19 vaccine based immunity. They also have a relative 70.3% higher expected utility from every 30 min spent acquiring the COVID-19 vaccine, and a 53.4% higher expected utility from every 100 AED spent on the vaccine.

The impact of occupation is only significant for individuals' willingness to get the vaccine (-0.365), for those working in governmental or semi-governmental institutions; however, it does not appear to significantly influence the maximum time, nor money individuals are willing to spend on their expressed vaccine preference. Indeed, compared to the individuals that are not working, those working in governmental or semi-governmental institutions appear show more COVID-19 vaccine hesitancy, with a relative 36.5% lower expected utility. Conversely however, self-employed or privately employed individuals appear to show no significant differences in willingness to get the COVID-19 vaccine, compared to those not working.

The impact of monthly income on individuals' COVID-19 vaccine preferences in much more decisive. Indeed, for every 1000 EAD increase in monthly income, it can be noted that expected utility from COVID-19 vaccination increases by 26%, while the expected utility of each unit of time (every 30 min) and money (every 100 AED) spent on getting the COVID-19 vaccine increases by

14 of 25

19.1% and 29.8%, respectively. These results suggest a general perception of the COVID-19 vaccine as a "normal good", since rising income increases individuals' willingness to get the vaccine in the UAE. Putting these findings within the context of our above discussions with the intercept terms (where it was suggested that individuals' perceptions of the interplay between the utility depleting COVID-19 disease, and its at least theoretically utility improving corresponding vaccine, would eventually shape their subjective preferences for the COVID-19 vaccines), the fact that the vaccine is perceived as a normal good, provides an empirical support for the theoretical utility improving proposition in our target population. Because increased income appear to reduce both the perceived opportunity cost of time and money spent on COVID-19 vaccine demand, all things being equal, if the prospective vaccine were to be affordable (whether free of charge or at a reduced fee), the prevailing outcome should be its general uptake in the UAE, contributing to creating the needed herd immunity, required to eradicate the disease from the UAE community.

The results from the place of residence suggest no significant difference in individuals expected utility from getting the vaccine, nor difference in expected utility from money spent doing so, across the different Emirates. However, a significant difference in expected utility from time spent getting the vaccine is observed between the different Emirates. In fact, Abu Dhabi and Dubai residents show 40.7% and 76.1%, respectively, higher expected utility from every prospective 30 min spent getting the COVID-19 vaccine, compared to residents of the remaining five Emirates. These spatial differentials in willingness to spend time in getting the vaccine may be due to the spatial differences in the impact of the COVID-19 pandemic, with the resulting differential measures that were implemented locally in each Emirate to curb to pandemic. Although restrictive measures were implemented nationwide, the sizes and strategic roles of the two Emirates of Abu Dhabi and Dubai as the federal capital and the tourism capital respectively, provided their residents with unique experiences during the COVID-19 pandemic, all of which contributed to shaping the spatial heterogeneity in perceived vaccine opportunity cost in the country.

5.2.3. The Impact of Personal and Peer Influences

The estimated individual and group specific influences on ones vaccine's preferences are summarized in the mid-portion of Table A6. It can be noted that the individuals reporting to be knowledgeable about vaccines highlight relatively more COVID-19 vaccine hesitancy (less willingness to get the vaccine), than their counterpart who do not. More specifically, they show a 29.2% higher expected dis-utility from COVID-19 vaccine based immunization than those reporting not knowing about vaccines. This finding seems to suggest that the information received by those reporting to knowing about vaccines, is perhaps of unfavorable nature. Indeed, the literature on general vaccine hesitancy has repeatedly shown the importance of the quality of vaccine information in the media, in shaping vaccine acceptance/refusal [10,12]. Both the rising prevalence of vaccine hesitancy, and anti-vaccine movement observed in different parts of the world, have been credited in the literature to misinformation on vaccines and their safety [49]. This situation has led [57] to propose good practices in developing sensitive communications that take into account the complexity of the cognitive processing and valuation of information for optimal community level vaccine uptake.

Indeed, of the 1109 study participants in the present analysis, 650 (58.61%) reported not getting enough information on vaccines and their safety, with only 209 (18.85%) identifying as "anti-vaxxer", against 900 (81.15%) who identified themselves otherwise [59], suggesting perhaps a low prevalence of anti-vaccine sentiments in the UAE. Our econometric findings however show no significant difference in vaccine hesitancy between those reporting to getting enough information on vaccine safety, and their counterparts reporting not. Conversely however, compared to those not getting enough information on vaccines and their safety, those reporting to getting such information show relatively 28.9% and 25.5% lower expected utility from each unit of time (every 30 min) and money (every 100 AED) spent on acquiring the COVID-19 vaccine. Thus, confirming further, the critical nature of the quality of vaccine communications in insuring better vaccine perception and uptake. Hence, building on

the recommendations by [57] to ensure general vaccine confidence, the fact that our findings show relatively more COVID-19 vaccine hesitancy and lower expected utility among individuals reporting to being knowledgeable about vaccines, suggest that future communications by UAE health authorities in relation to the prospective COVID-19 vaccine could benefit from (i) establishing trust, (ii) providing both the risks and benefits of the COVID-19 vaccine, (iii) giving the facts before addressing the myths, (iv) using visual aids, and finally (v) testing alternative communication materials prior to launching the COVID-19 vaccination program in the UAE.

With regards to respondents' past experience with vaccines, our econometric results show no significant difference in vaccine hesitancy, nor willingness to spend time getting the COVID-19 vaccine between individuals with prior vaccine refusals, and those without. However, it can be noted that individuals with prior vaccine refusal show a significant 27.7% lower expected utility from each 100 AED increase spending on getting the COVID-19 vaccine. These findings suggest that individuals with prior vaccine refusals are not necessarily more hesitant towards, nor unwilling to get vaccinated against the coronavirus disease, but perhaps are relatively more cost sensitive/financially constrained; a situation that may contribute to impeding their COVID-19 vaccine uptake. Given that this group represent 24.80% of our studied sample, and that herd immunity are reported at around 75% effective vaccine coverage in the population, ensuring COVID-19 vaccine affordability (whether free of charge, or at a significantly reduced fee) in the UAE, would be key to ensuring the effectiveness of the prospective COVID-19 vaccine program, in eradicating the pandemic from the general population.

Similarly, our econometric results show no significant difference in vaccine hesitancy, nor willingness to spend time getting the COVID-19 vaccine between individuals with prior knowledge of a bad vaccine reaction, and those without. However, it can be noted that those reporting to have such prior knowledge of someone with a bad vaccine reaction still paradoxically exhibit 45.2% more expected utility from each 100 AED increase spending on acquiring the COVID-19 vaccine. This paradoxical finding seems to suggest that knowing someone that has had an adverse reaction to a vaccine, does not necessarily discourage individual financial investment to acquiring vaccine based immunity, but rather seem to contribute to the individual being willing to invest more money, perhaps to get a quality vaccine with better perceived safety.

With regards to the perceived subjective norm of the COVID-19 vaccine, our econometric findings show that the stronger one believes that everyone should get the vaccine once available, the more accepting one is of the COVID-19 vaccine for oneself, and the greater one's willingness to spend time, and also money in acquiring the COVID-19 vaccine. More specifically, each level increase in such belief appears to raise individuals' expected utility from COVID-19 vaccination by 66.6%; while raising their expected utility from time (every 30 min) and money (every 100 AED) spent by 39.1% and 65.5%, respectively. These latter findings seem to suggest that the UAE's prospective COVID-19 vaccination program could benefit further in effectiveness, by leveraging socio-collective values in the UAE community, through COVID-19 vaccine communications that highlight individuals' inter-dependence in resolving the COVID-19 pandemic in the nation.

On the impact of religious and moral convictions on individuals' COVID-19 vaccine preferences, it can be noted from Table A6 that religious or moral convictions do not significantly determine differences in vaccine hesitancy, nor willingness to spend time, nor money in getting the COVID-19 vaccine in the UAE. However, individuals perceiving such convictions based vaccine refusal as health risks exhibit relatively 22% higher expected utility from every 30 min spent getting the COVID-19 vaccine. This latter finding seems to suggest that risk perception is indeed a significant motivator of COVID-19 vaccine seeking behavior in the UAE, in terms of the time the average person is willing to spend to get vaccinated.

5.2.4. The Impact of Contextual and Vaccine Specific Influences

The results of the impact that COVID-19 information source has on vaccine demand suggest no significant differences in vaccine hesitancy, nor willingness to spend time, nor money in getting the

COVID-19 vaccine, across the various sources of COVID-19 information in the UAE. These findings seem to suggest that irrespective of whether COVID-19 messages are communicated through government websites, the general internet, or other channels of communications, the medium through which the information is transmitted is not as important as the quality of the message in insuring successful vaccine uptake.

Our findings show however that perceived COVID-19 vaccine importance significantly raises COVID-19 vaccine acceptance, as well as individuals willingness to spend time, and money in acquiring the vaccine. Indeed, every level increase in perceived vaccine importance raises by 38.8% individuals expected utility from COVID-19 vaccine uptake, In addition to raising by 41.2% and 32.4%, respectively the expected utility from each unit of time (every 30 min) and money (every 100 AED) spent getting vaccinated. With respect to individuals' concerns about the COVID-19 vaccine, it can be noted that while increased levels of concerns about the vaccine significantly raises COVID-19 vaccine acceptance, it reduces however individuals willingness to spent time, while leaving unaffected their willingness to spend money to acquire the COVID-19 vaccine. Indeed, each increased level of concern for the vaccine is seen to raises by 13.6% individuals expected utility from COVID-19 vaccine uptake, while reducing by 17% the expected utility from every 30 min spent getting vaccinated.

Our results further show that the administration mode of the prospective COVID-19 vaccine is a significant determinant of individuals' vaccine demand. In fact, compared to those that prefer not to get vaccinated, those that prefer oral administration, injection and nasal spray of the vaccine all show greater expected utility from COVID-19 vaccine uptake, and are also relatively more willing to spent time and money to get the vaccine. Indeed, the results show that compared to those preferring not to get vaccinated, those that prefer oral administration, injection and nasal spray of the COVID-19 vaccine exhibit 59.2%, 69.5% and 61.7% higher expected utility from COVID-19 vaccine uptake, respectively. Similarly, compared to those preferring not to get vaccinated, those preferring oral administration, injection and nasal spray of the COVID-19 vaccine utility from every 100 AED spent on getting the vaccine, respectively. Moreover, while those with oral administration shown no significant difference with their counterparts that prefer not to get vaccinated, compared to member of the latter group, individuals preferring injection and nasal spray of the prospective COVID-19 vaccine show 54.7% and 97.9%, respectively, higher expected utility from every 30 min spent getting vaccinated.

On the influences of perceived barriers to COVID-19 vaccine uptake, it can be noted that financial, temporal and spatial constraints significantly shape COVID-19 vaccine preferences in the UAE. Indeed, starting with the financial constraint, it can be noted that compared to individuals reporting the financial cost of the prospective COVID-19 vaccine to not be a potential barrier to their vaccine uptake, those reporting such barrier show over 100% lower expected utility from COVID-19 vaccine uptake, with a significant 95.1% lower expected utility from every 100 AED spent on getting the vaccine. Moving to the temporal constraint, it can be noted that compared to the individuals that are unwilling, those reporting to being willing to travel over an hour to get the COVID-19 vaccine do exhibit 75% higher expected utility from COVID-19 vaccine uptake, with respectively 59.7% and 47.7% higher expected utility from every 30 min, and every 100 AED spent on getting vaccinated. A similar pattern is observed with the spatial constraint, where compared to the individuals that are unwilling to travel to a different emirate to get the vaccine if not available in their immediate emirate of residence, those reporting to being willing to travel do exhibit 63.3% higher expected utility from every 30 min, and every 100 AED spent traveling to mevery 30 min, and every 100 AED spent willing for every 30 min, and every 100 AED spent traveling to another emirate to get the COVID-19 vaccine.

Given that for all three perceived barriers, the constraints are binding for at least 33% of the study participants, the required 75% effective immunization coverage for herd immunity may be compromised if mitigating measures are not put in place to overcome the perceived financial, temporal and spatial constraints to vaccine uptake. A situation most likely to also compromise the efforts of any prospective COVID-19 vaccine program in the country. Potential mitigating measures

of these perceived barriers could include : (i) ensuring the availability of the vaccine locally in each Emirate to reduce/eliminate the need for cross-Emirate travels to get vaccinated (to circumvent the spatial constraint); (ii) within each emirate, ensuring also the geographical distribution of vaccines across health centers to reduce the travel time to get the vaccine (to circumvent the temporal constraint); and finally (iii) ensuring that the available vaccine is also financially affordable to the average person, whether free of charge or at a reduced fee (to circumvent the financial constraint). Our results suggest that taking such measures would contribute to the overall effectiveness of the prospective COVID-19 vaccination program in the UAE, and therefore help eradicate the COVID-19 pandemic from the country.

6. Conclusions

The Quadruple Helix model stipulates that under the triple helix framework of academia, industry and government, emerging technologies do not always match the demand and needs of society, limiting therefore their potential social impact [72]. Since a high social uptake of the prospective COVID-19 vaccine remains crucial to effectively eradicate the pandemic, understanding the preferences of the fourth helix is key to insuring the needed trust and support for medical biotechnology based novel therapeutics against the SARS-COV-2 [48]. To that end, this study relied on Random Utility Theory to provide a behavioral health model for stated vaccine preferences analysis. The model was then used to analyze individuals' demand for the prospective COVID-19 vaccine in the United Arab Emirates. In doing so, our research contributed methodologically to the evidence on vaccine technology acceptance. It also contributed to the nascent empirical evidence on the novel COVID-19 disease, which still remains a great deal of a puzzle to the global scientific community. More specifically, our study answered to the following questions with respect to the COVID-19 pandemic:

- What are the determinants and the extent of COVID-19 vaccine acceptance in the UAE?
- How much time are individuals willing to spend to get the COVID-19 vaccine in the country?
- How much money are individuals willing to pay for the COVID-19 vaccine in the country?

Answering the above research questions have fundamental implications for the successful deployment of an effective immunization program to eradicate the pandemic from the UAE. By assuming the existence of a market for COVID-19 vaccine, where vaccine producers meet and trade with potential and actual vaccine consumers; it could be predicted through standard micro-economic theory that the demand for the prospective vaccine by individual consumers, would depend on their willingness and ability to pay (directly and/or indirectly) for the vaccine, as a health good. As such, looking at the perceived direct and indirect costs of the COVID-19 vaccine to the average person in the UAE health/economic system, provides an important insight into its likely uptake in the country. Furthermore, since at the population level herd immunity is reported at around 75% effective vaccination rate, vaccine affordability (in terms of low direct and indirect cost) becomes critical for ensuring that individuals are willing and able to get vaccinated.

Following the analysis, we found that in addition to socio-economic and demographic influences, the factors affecting individuals' utility and thus preferences for the prospective COVID-19 vaccine in the UAE include individual and group influences, vaccine specific influences, and contextual influences, as put forth by the WHO SAGE group on immunization, through their matrix of vaccine demand determinants [14]. After estimation of the system modeled on the utility scale, the intercept terms of the equations describing the indirect cost (time willing to spend) and the direct cost (money willing to spend) processes, identified the minimum amount of time, and the minimum amount of money the average person was willing to spend to get the COVID-19 vaccine in the UAE. On the direct cost of the prospective vaccine, we found a statistically significant $\beta_{30} = -1.760$, suggesting that the average person expects a 176 AED (or 47.92 USD) increased dis-utility from every 100 AED (or 27.23 USD) increased spending to acquire the COVID-19 vaccine. In other words the expected marginal

utility for every dirham (1 AED) spent on getting the COVID-19 vaccine by the average person is -1.76 AED.

Conversely, based on the indirect cost of vaccine, we found a statistically insignificant $\beta_{20} = -0.132$, which suggests an expected dis-utility from every 30 min spent to get the COVID-19 vaccine. Since statistical insignificant, we deduce that the expected time spent acquiring the COVID-19 vaccine, as an indirect cost is non-binding in the COVID-19 vaccine decision-making process of the average person in the UAE. We also found a significant $\beta_{10} = -2.131$, suggesting an expected 2.131 increased dis-utility along the vaccine continuum, for the average individual seeking to get vaccinated. These results seemed to suggest that all things equal, spending time and money to acquire the prospective COVID-19 vaccine, is perceived as utility depleting by the average person in the UAE.

Furthermore, our analysis pointed out significant perceived financial, temporal and spatial barriers to COVID-19 vaccine uptake in the UAE. Therefore, a set of measures were suggested in light of these results to raise the likely effectiveness of the prospective COVID-19 vaccination program in the country, including (i) ensuring the availability of the vaccine locally in each emirate to reduce/eliminate the need for cross-emirate travels to get vaccinated; (ii) ensuring also the geographical distribution of vaccines across health centers to reduce the travel time to get the vaccine within each emirate; and finally (iii) ensuring the affordability of the available vaccine to the average person whether free of charge or through subsidy.

Though our analysis puts forth significant methodological contributions, with equally important practical suggestions, the study also presents few limitations worth mentioning: First, due to authors' adherence to social distancing, individuals' responses to this study were recorded using a web-based self-administered survey questionnaire, instead of a direct face-to-face interview, increasing the risk of potential bias in individuals' responses reporting. Second, the study is cross-sectional in nature, and therefore depicts a picture of individuals' stated preferences for the prospective COVID-19 vaccine in the UAE between 4 July and 4 August 2020. Not only does this make it challenging to disentangle causal relationships between the COVID-19 vaccine preference outcome and its determinant factors; an individual's revealed preference for the vaccine once actually available might also be different from her/his initially stated vaccine preferences for the COVID-19 vaccine might also change overtime, as such it would be equally interesting to address such behavioral dynamic in prospective investigations. In this case, experimental and/or longitudinal study designs often offer suitable alternatives and should be considered to validate our cross-sectional findings.

From an open innovation perspective [73-76], the above mentioned limitations could be also be linked to the "Collingridge dilemema", whereby the full functionality and impact of the prospective biotechnology based novel therapeutic against the SARS-COV-2, cannot be easily predicted until it is sufficiently developed and widely used. Moreover, since technology itself is generally characterized by uncertainty, complexity and ambivalence, the potential ramifications inherent in introducing a novel COVID-19 vaccine are extremely difficult to predict, for biomedical technology experts and health authorities, let alone the general public. Nonetheless, by relying on a novel Random Utility Theoretic framework and a random sample of respondents spanning all seven emirates of the UAE, to uncover the public's preferences for the prospective COVID-19 vaccine within the context of a Quadruple Helix innovation system, this study is pioneering in so many respects worth extending further in prospective investigations on the topic. Since non-pharmaceutical control measures such as face masking, social distancing and frequent hand sanitation are the only reasonable solutions to limiting the societal impact of the pandemic at the moment, our next focus on the topic will consider exploring individuals' adherence to such self-directed behavioral health measures in the UAE. Other prospective investigations could also consider such future avenues in other national settings, as a way of contributing further to the evidence based policy making required to eradicate the COVID-19 pandemic from communities around the world.

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Appendix A

Variables	Description	Freq (n)	%
	0—Not at all	279	25.16
	1—A little	229	20.65
WTGCoVacc	2—A moderate amount	356	32.10
	3—Quite a bit	245	22.09
	0—None	63	05.68
	1—[0 to 30 min]	512	46.17
	2—[30 to 60 min]	95	08.57
Max1imWillgSpndCoVacc	3—[60 to 90 min]	57	05.14
	4—[90 to 120 min]	242	21.82
	5—[120 min and over]	140	12.62
	0-0 AED	284	25.61
	1-[0 to 100 AED]	444	40.04
	2-[100 to 200 AED]	146	13.17
MaxWTPCoVacc	3-[200 to 300 AED]	87	07.84
	4-[300 to 400 AED]	31	02.80
	5—[400 to 500 AED]	51	04.60
	6—[500 AED and over]	66	05.95

Table A1. Vaccine Outcome Variables (n = 1109).

Source: Authors' construction using data openly available at [59] and formally published in [58].

Table	A2.	. Socio	-economic	and	demog	graphic	character	ristics	of th	e partici	pants	(n =	1109	€).
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Variables	Description	Freq (n)	%
	1—[18 to 25 years]	143	12.89
	2—[26 to 35 years]	310	27.95
AGE	3—[36 to 45 years]	437	39.40
	4—[45 years and over]	219	19.75
Condor	0—Male	309	27.86
Genuer	1—Female	800	72.14
MariStat	0—Single/separated/divorced/widowed	249	22.45
Mansial	1—Married	860	77.55
Nationality	0—Emirates	246	22.18
Nationality	1—Non-Emirates	863	77.82
	1—High School at most	156	14.07
T. J C	2—Diploma	125	11.27
Education	3—Graduate	655	59.06
	4—Postgraduate	173	15.60
	1—Not working	388	34.99
Occupation	2- (Semi)government	331	29.84
	3—PrivateandSelf-employed	390	35.17
	0—None	149	13.44
	1—less than 10,000 EAD	344	31.02
IncomeMonthly	2—less than 20,000 EAD	275	24.80
, ,	3—less than 30,000 EAD	184	16.59
	4—Above 30,000 EAD	157	14.16
	1—Abu Dhabi	796	71.78
Reside	2—Dubai	129	11.63
	1—Others	184	16.59

Source: Authors' construction using data openly available at [59] and formally published in [58].

Variables	Description	Freq (n)	%
	Knowledge and Information on vaccines		
KnowVaccine	0—No	478	43.10
	1—Yes	631	56.90
EnouInfVacSafty	0—No	650	58.61
2	1—Yes	459	41.39
	Past Experiences with vaccines		
EverNOTvaccin	0—No	834	75.20
	1—Yes	275	24.80
Any1BadReactVac	0—No	876	78.99
	1—Yes	233	21.01
	Subjective Norm		
	0—Not at all	113	10.19
ImportnCoVacEvery1	1—A little	99	08.93
1	2—A moderate amount	232	20.92
	3—Quite a bit	665	59.96
	Religious and Moral Convictions		
NoVaccRelgCult	0—No	984	88.73
_	1—Yes	124	11.27
D11 114	0—No	384	34.63
KiskngHlth	1—Yes	724	65.37

Table A3. Personal and Peer Influences on individual perceived COVID-19 vaccine utility (n = 1109).

Source: Authors' construction using data openly available at [59] and formally published in [58].

Table A4. Contextual and vaccine specific influences on individual perceived COVID-19 vaccine utility (n = 1109).

variables	Description	Freq (n)	%
	Source of COVID-19 Information		
	Others	252	22.72
InfoSrceCov	Government website	373	33.63
	General Internet	484	43.64
	Perception of COVID-19 vaccine importance		
	0—Not at all	106	09.56
ImportnCoVacc	1—A little	88	07.94
-	2—A moderate amount	244	22.00
	3—Quite a bit	671	60.50
	Concerns about COVID-19 vaccine		
	0—Not at all	100	09.02
	1—A little	160	14.43
ConcernCoVacc	2—A moderate amount	394	35.53
	3—Quite a bit	455	41.03
	Preferred mode of administration		
	of the prospective COVID-19 vaccine		
	None	239	21.55
CoVaccPrefAdmnMod	Orally	310	27.95
	Injected	488	44.00
	Nasal spray	72	06.49
	Perceived barriers to COVID-19 vaccine's uptake		
	(Financial constraint)		
FinCostCoVacPrevGet	0—No	532	47.97
	1—Yes	577	52.03
	(Time constraint)		
TravalOver1HrCoVace	0—No	366	33.00
InavelOver1HiCovacc	1—Yes	743	67.00
	(Spatial constraint)		
TravelDiffEmirCoVacc	0—No	403	36.34
	1—Yes	706	63.66

Source: Authors' construction using data openly available at [59] and formally published in [58].

Table A5. Chi-square test results for the three outcome variables with the explanatory factors in the model.

	WTGCoVacc		MaxTim	MaxTimWillgSpndCoVacc			MaxWTPCoVacc		
	Stat	df	<i>p</i> -Value	Stat	df	<i>p</i> -Value	Stat	df	<i>p</i> -Value
WTGCoVacc				292.7 ***	15	$<$ 2.2 \times 10 ⁻¹⁶	416.4 ***	30	$<$ 2.2 \times 10 ⁻¹⁶
MaxWTPCoVacc				666.5 ***	18	$< 2.2 imes 10^{-16}$			
Age	20.4 *	9	0.01564	58.6 ***	15	${<}4.5 imes10^{-7}$	46.4 ***	18	0.00026
Gender	20.6 ***	3	0.00013	82.1 ***	5	$2.9 imes 10^{-16}$	57.8 ***	6	$1.3 imes 10^{-10}$
MariStat	4.45	3	0.21730	20.7 ***	5	0.00094	8.5 ***	6	0.20670
Nationality	27.2 ***	3	$5.3 imes 10^{-6}$	18.7 **	5	0.00218	59.9 ***	6	$4.7 imes 10^{-11}$
Education	17.1 *	9	0.04670	69.5 ***	15	$5.4 imes10^{-9}$	56.4 ***	18	$7.7 imes10^{-6}$
Occupation	12.4	6	0.05294	33.3 ***	10	0.00025	33.9 ***	12	0.00069
IncomeMonthly	70.8 ***	12	$2.3 imes10^{-10}$	69.4 ***	20	$2.3 imes10^{-7}$	142.3 ***	24	$< 2.2 imes 10^{-16}$
Reside	13.3 *	6	0.03818	60.9 ***	10	$2.5 imes 10^{-9}$	20.1	12	0.06436
KnowVaccine	1.98	3	0.57680	17.6 **	5	0.00349	10.3	6	0.1142
EnouInfVacSafty	15.7 **	3	0.00130	7.7	5	0.17200	8.5 ***	6	0.20280
EverNOTvaccin	79.5 ***	3	${<}2.2 imes10^{-16}$	23.9 ***	5	0.00022	76.3 ***	6	$2.1 imes10^{-14}$
Any1BadReactVac	36.3 ***	3	6.6×10^{-8}	13.4 *	5	0.01954	29.2 ***	6	$5.5 imes 10^{-5}$
ImportnCoVacEvery1	419.6 ***	9	$<$ 2.2 $ imes$ 10 $^{-16}$	319.7 ***	15	$< 2.2 imes 10^{-16}$	369.9 ***	18	$<\!\!2.2 imes 10^{-16}$
NoVaccRelgCult	33.4 ***	3	2.6×10^{-7}	10.1	5	0.07204	25.1 ***	6	0.00033
RiskngHlth	203.8 ***	3	$<$ 2.2 $ imes$ 10 $^{-16}$	163.7 ***	5	$< 2.2 imes 10^{-16}$	178.5 ***	6	$< 2.2 imes 10^{-16}$
InfoSrceCov	7.4	6	0.28840	26.9 **	10	0.00267	27.1 ***	12	0.00745
ImportnCoVacc	366.8 ***	9	$<$ 2.2 $ imes$ 10 $^{-16}$	343.6 ***	15	$< 2.2 imes 10^{-16}$	312.7 ***	18	$<\!\!2.2 imes 10^{-16}$
ConcernCoVacc	99.9 ***	9	<2.2 $ imes$ 10 ⁻¹⁶	141 ***	15	$<\!\!2.2 imes 10^{-16}$	52.8 ***	18	2.8×10^{-5}
CoVaccPrefAdmnMod	248.8 ***	9	$<$ 2.2 \times 10 ⁻¹⁶	213.7 ***	15	$<\!\!2.2 imes 10^{-16}$	246.6 ***	18	$<\!\!2.2 imes 10^{-16}$
FinCostCoVacPrevGet	223.1 ***	3	<2.2 $ imes$ 10 ⁻¹⁶	71.2 ***	5	5.8×10^{-14}	129.7 ***	6	$< 2.2 imes 10^{-16}$
TravelOver1HrCoVacc	328.3 ***	3	$< 2.2 imes 10^{-16}$	196.6 ***	5	$< 2.2 \times 10^{-16}$	254.2 ***	6	$<$ 2.2 \times 10 ⁻¹⁶
TravelDiffEmirCoVacc	289.9 ***	3	$<$ 2.2 \times 10 ⁻¹⁶	171.8 ***	5	$< 2.2 \times 10^{-16}$	244.9 ***	6	$< 2.2 \times 10^{-16}$

Source: Authors' construction using data openly available at [59] and formally published in [58]; *** p < 0.001, ** p < 0.01, *p < 0.05.

Table A6. Performance measures of the Multivariate Probit and Multivariate Logit specifications.

Link	Threshold	Nsubjects	ndim	logPL	CLAIC	CLBIC	Fevals
mvprobit	fix1first	1109	3	-7954.14	16,346.81	17,445.57	54,494
mvlogit	fix1first	1109	3	-7953.22	16,345.22	17,444.64	65,153

Note: Produced from Maximum Composite Likelihood estimation of the MVORM, for Model comparison.

Table A7. Maximum Composite Likelihood estimates of the Multivariate Logit Model Specification.

	WTGCoV	acc	Maxtimwillgsp	ndcovacc	Maxwtpcovacc		
	Coeff.	(S.E.)	Coeff.	(S.E.)	Coeff.	(S.E.)	
Cutoff 2	$\theta_{12} = 1.598$ ***	(0.103)	$\theta_{22} = 3.918^{***}$	(0.229)	$\theta_{32} = 2.565$ ***	(0.120)	
Cutoff 3	$\theta_{13} = 3.777 ***$	(0.155)	$\theta_{23} = 4.351$ ***	(0.231)	$\theta_{33} = 3.417^{***}$	(0.139)	
Cutoff 4			$\theta_{24} = 4.609^{***}$	(0.233)	$\theta_{34} = 4.078^{***}$	(0.156)	
Cutoff 5			$\theta_{25} = 6.080^{***}$	(0.253)	$\theta_{35} = 4.383$ ***	(0.164)	
Cutoff 6					$\theta_{36} = 5.091^{***}$	(0.198)	
(Intercept)	-2.131 ***	(0.458)	-0.132	(0.366)	-1.760 ***	(0.443)	
Socio-economic influences							
Age	-0.163 *	(0.083)	-0.131	(0.080)	-0.122	(0.082)	
Gender(female)	-0.063	(0.160)	-0.167	(0.150)	-0.240	(0.154)	
MariStat	-0.054	(0.187)	-0.172	(0.174)	-0.617 ***	(0.172)	
Nationality(non-Emirates)	-0.682 ***	(0.185)	0.417 *	(0.176)	-0.501 **	(0.177)	
Education(diploma)	0.006	(0.269)	-0.108	(0.255)	-0.095	(0.268)	
Education(graduate)	0.371 *	(0.202)	0.088	(0.192)	0.398 *	(0.203)	
Education(postgrad)	0.455 *	(0.266)	0.703 **	(0.248)	0.534 *	(0.259)	
Occupation(Semi)government	-0.365 *	(0.178)	-0.028	(0.171)	0.144	(0.183)	
Occupation(Private and&SelfEmp)	-0.047	(0.164)	-0.214	(0.156)	0.151	(0.168)	
IncomeMonthly	0.260 ***	(0.058)	0.191 ***	(0.055)	0.298 ***	(0.056)	
Reside(Abu Dhabi)	-0.004	(0.189)	0.407 *	(0.169)	-0.021	(0.179)	
Reside(Dubai)	0.064	(0.277)	0.761 **	(0.240)	0.196	(0.268)	

	WTGCoVacc		Maxtimwi	llgspndcovacc	Maxwtpcovacc		
	Coeff.	(S.E.)	Coeff.	(S.E.)	Coeff.	(S.E.)	
Personal and Peer influences							
KnowVaccine	-0.292 *	(0.135)	0.249 *	(0.134)	-0.052	(0.133)	
EnouInfVacSafty	0.086	(0.132)	-0.289 *	(0.128)	-0.255 *	(0.131)	
EverNOTvaccin	0.122	(0.159)	0.231	(0.160)	-0.277 *	(0.159)	
Any1BadReactVac	-0.005	(0.170)	0.185	(0.173)	0.452 **	(0.175)	
ImportnCoVacEvery1	0.666 ***	(0.108)	0.391 **	(0.119)	0.655 ***	(0.109)	
NoVaccRelgCult	-0.033	(0.226)	0.079	(0.216)	-0.096	(0.226)	
RiskngHlth	-0.081	(0.168)	0.330 *	(0.169)	-0.033	(0.167)	
Vaccine specific influences							
InfoSrceCov(Gov. website)	-0.136	(0.174)	-0.151	(0.162)	0.047	(0.172)	
InfoSrceCov(General Internet)	-0.148	(0.170)	-0.164	(0.162)	0.172	(0.167)	
ImportnCoVacc	0.388 ***	(0.107)	0.412 ***	(0.114)	0.324 **	(0.111)	
ConcernCoVacc	0.136 *	(0.078)	-0.170 *	(0.072)	-0.080	(0.075)	
CoVaccPrefAdmnMod(Orally)	0.592 **	(0.211)	-0.032	(0.208)	0.646 **	(0.201)	
CoVaccPrefAdmnMod(Injected)	0.695 ***	(0.211)	0.547 **	(0.198)	0.546 **	(0.196)	
CoVaccPrefAdmnMod(Nasal spray)	0.617 *	(0.315)	0.979 ***	(0.284)	1.288 ***	(0.273)	
FinCostCoVacPrevGet	-1.611 ***	(0.148)	-0.136	(0.131)	-0.951 ***	(0.140)	
TravelOver1HrCoVacc	0.750 ***	(0.195)	0.597 **	(0.199)	0.374 *	(0.198)	
TravelDiffEmirCoVacc	0.633 ***	(0.182)	0.477 **	(0.184)	0.742 ***	(0.193)	
Corr $(\epsilon_{i1}, \epsilon_{i2})$	0.212 ***	(0.043)					
Corr $(\epsilon_{i1}, \epsilon_{i3})$			0.430 ***	(0.036)			
$\operatorname{Corr}\left(\epsilon_{i2},\epsilon_{i3}\right)$				· · ·	0.365 ***	(0.038)	

Table A7. Cont.

Source: Authors' construction using data openly available at [59] and formally published in [58]; *** p < 0.001, *p < 0.01, *p < 0.05.

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