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Herding behavior in COVID-19 vaccine hesitancy in rural Zimbabwe: The moderating role of health information under heterogeneous household risk perceptions

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ABSTRACT

COVID-19 vaccine hesitancy poses a global health threat by potentially delaying the attainment of herd immunity to attenuate infection and transmission. Most governments across the world are engrossed with formulating strategies to surmount conservative group behavior such as vaccine hesitancy typical under risky and uncertain situations such as in the case of COVID-19. This paper examines herding behavior in vaccine hesitancy with a special focus on the moderating role of household access to health information from village health workers under different risk perceptions. We use the 2021 Zimbabwe Vulnerability Assessment Committee cross-section household national survey consisting of 13, 583 valid observations. Our major findings indicate that herding behavior plays a role in rural households' hesitancy to COVID-19 vaccine inoculation. Furthermore, whilst access to health information from village health workers reduces herding behavior in vaccine hesitancy, it does so more when the household perceives itself to be at high risk of contracting COVID-19. Analysing herding behavior in vaccine hesitancy can help policymakers develop more targeted vaccination strategies, such as promoting access to health information through channels like village health workers, especially for households at high risk of contracting COVID-19.

1. Introduction

Mass vaccinations have been touted as a mitigation measure to achieve herd immunity in the fight against the COVID-19 pandemic (Godlee, 2019; Harrison and Wu, 2020). Notwithstanding the burgeoning evidence on the potency of mass vaccinations in curtailing the spread of infectious diseases and increasing accessibility of COVID-19 vaccines, vaccine hesitancy jeopardizes attainment of herd immunity across and within countries (Alsan and Wanamaker, 2018; Alsan et al., 2019; Martinez-Bravo and Stegmann, 2017). Extant studies have demonstrated vaccine hesitancy in other settings (e.g., Banerjee et al., 2010; Blasi et al., 2011; Dupas and Miguel, 2017; Dupas, 2011; Kok et al., 2010; SteelFisher et al., 2010). Mistrust of the health care system (e.g., Furnham, 2007; Gilles et al., 2011; Lahijani et al., 2020), uncertainties about individual risk of contracting COVID-19 (e.g., Gust et al., 2004; Opstelten et al., 2010; Quinn et al., 2009) and safety of the newly developed COVID-19 vaccines (e.g., Blasi et al., 2011; Bults et al., 2011; Schwarzinger et al., 2010; Vırseda et al., 2010), are amongst the major drivers of vaccine hesitancy. Additionally, dearth of confidence in the credibility of the country of origin of the vaccine also breeds hesitancy.

Confronted by such uncertainties and the costliness of acquiring information about COVID-19 and the COVID-19 vaccines' efficacy, rather than deciding independently and atomistically on the basis of their own private information about COVID-19 vaccination, it might become optimal for rational agents to adopt a "wait and see" strategy, deferring vaccination until their peers have been vaccinated, triggering "herding behavior" in vaccine hesitancy (Bauch, 2005; Bhattacharyya and Bauch, 2011; Fu et al., 2011; Maurer et al., 2010; Smith et al., 2011). Herding behavior is defined as following others and imitating group behaviors rather than using own information in making private decisions (Banerjee, 1992). Whilst the "wait and see" strategy may seem optimal from a private perspective; it is socially suboptimal as the cost of acquiring information may lead to accelerated infection rate due to delays in the attainment of herd immunity. Thus the "wait and see" approach creates a market failure which may be corrected by influencing or 'nudging'

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agents to get vaccinated through provision of health information on the advantages of COVID-19 vaccination via channels such as village health workers (see e.g., Camerer et al., 2003; Thaler and Sunstein, 2008). Positive response to the health information nudge is *a priori* a function of individual perceptions of risk of contracting COVID-19 amongst other factors (Dryhurst et al., 2020; Ning et al., 2020; Wise et al., 2020).

Vaccine hesitancy has been identified in theory as the major cause of vaccine refusal (Salathé and Bonhoeffer, 2008). Surmounting vaccine hesitancy is an arduous, yet critical task for public health and government officials aiming to achieve head immunity amid swelling rates of COVID-19 infections and deaths. This paper seeks to provide timely evidence on some of the factors that can be targeted to improve vaccination rates in the fight to put COVID-19 under control. Specifically, this paper speaks to the literature on herding behavior, risk, access to health information and the inter-linkages thereof with vaccine hesitancy. We employ data emanating from a large-scale cross-sectional survey of rural households in Zimbabwe conducted in 2021. In particular, we seek answers to the following three interrelated questions. First, is there herding behavior in vaccine hesitancy in rural Zimbabwe? Second, does access to health information from village health workers mitigate herding behavior in vaccine hesitancy? Finally, is there risk heterogeneity in the mitigatory effects of health information on herding behavior in vaccine hesitancy? Building on recent studies that propose that agents mimic decisions of peers in their social networks (see e.g., Bandiera and Rasul, 2006; Boahene et al., 1999; Conley & Udry, 2001; Kumar et al., 2022; Miguel and Kremer, 2004), we exploit household GPS coordinates to construct a social network of vaccine hesitant households that a household could mimic. Delineation of the household's social network of vaccine hesitant households is only the first step in determining the existence of herding behavior in vaccine hesitancy amongst households. The second order condition of identification of herding behavior in vaccine hesitancy necessitates neutralization of other factors that may also produce homogenous behavior among peers (Manski, 1993). We follow Matuschke and Qaim (2009) to control for the location level effects as well as the characteristics of the peers in the network of the household.

We arrive at three results on herding behavior, risk, access to health information and the impact thereof on vaccine hesitancy. First, herding behavior contributes to vaccine hesitancy in rural Zimbabwe. The larger the number of vaccine hesitant households there are in the household's social network, the more likely the household is to hesitate in accepting the COVID-19 vaccines that are on offer in Zimbabwe. This situation confirms herding behavior in vaccine hesitancy in rural Zimbabwe. Second, household access to the health information from village health workers is associated with a decline in the individual propensity to move with the herd in vaccine hesitancy. Once a household has access to health information from village health workers, the household's probability of following the herd in hesitating the newly developed COVID-19 vaccine is reduced, propelling the household towards vaccination. Access to health information from village health workers therefore reduces the information acquisition costs *vis-à-vis* the newly developed vaccine. Finally, households that are at high risk of contracting COVID-19 reduce herding behavior more in the presence of health information from village health workers than those that are at low risk of contracting COVID-19. Studying herding behavior in vaccine hesitancy can help policy makers to create more targeted COVID-19 vaccination strategies such as the promotion of information dissemination through village health workers more so for households that are at high risk of COVID-19 infection.

The rest of this paper is organized as follows. The upcoming section reviews literature and specifies hypotheses examined in this study. Section 3 discusses our empirical strategy whilst Section 4 provides a discussion of results. Finally, Section 5 concludes.

2. Literature review and hypotheses

The decision to get vaccinated for a rational individual follows both economic and epidemiological incentives (Francis, 1997; Geoffard and Philipson, 1996, 1997; Sadique et al., 2005). It is anchored on available information concerning the effectiveness of the vaccine, risks and known side effects as well as prognosis of the disease. If such information is inadequate or scant such as in the case of COVID-19 disease and vaccines, people base their decisions on subjective risk and preference projections. In addition, the decision to get vaccinated itself ceases to be a static and discrete one of simply whether or not to get vaccinated, but the timing also becomes essential (Sadique et al., 2005). As individuals adopt a wait and see attitude, the likelihood to mimic others or "follow the herd" as it were increases (Bauch, 2005; Bhattacharyya and Bauch, 2011; Cohen et al., 2013; Fu et al., 2011; Maurer et al., 2010; Smith et al., 2011). The paucity of information such as in the COVID-19 case and the shortness in observational time for the few vaccinated individuals compels the majority of people to appeal to emotions and beliefs awaiting "convincing facts" (Dube et al., 2013; Kumar et al., 2022; Stanovich and West, 2000; Tversky and Kahneman, 1974) thereby adopting a wait and see attitude which is grounded on the heuristic of safety in numbers (Tversky and Kahneman, 1974). The safety in numbers ideology or herding behavior against the backdrop of vaccine scepticism results in a heightened level of vaccine hesitancy. This background leads us to our first hypothesis.

Hypothesis 1. Household propensity to be vaccine hesitant increases with the number of vaccine hesitant households within its social network.

Vaccine hesitancy diminishes significantly in the presence of mutual trust between communities and the public health sector (Attwell et al., 2018; Kerr et al., 2020; Palamenghi et al., 2020; Verger and Dube, 2020). A sizable number of the population trusts expert advice from public health workers more than from friends, family and books if they have trust in the public health sector (Gust et al., 2008; Lahariya, 2020; Wheeler and Buttenheim, 2013). Even the hard to please members of society who feel empowered in making decisions regarding their personal health and are critical of health services and products tend to respect opinions of well-informed, assertive and friendly public health professionals rather than follow the herd in vaccine hesitancy (Hak et al., 2005; WHO, 2013; Yaqub et al., 2014). Accordingly Johns (1998), proclaims that advice to get vaccinated in itself is not as important as the institutions from which that advice is coming. Public health workers such as village health workers in the context of Zimbabwe can thus be deployed as ambassadors to nudge households towards reducing vaccine hesitancy (WHO & UNICEF, 2021). This leads us to our second hypothesis linking access to health information from village health workers and propensity to follow the herd in vaccine hesitancy.

Hypothesis 2. Household's propensity to follow the herd in vaccine hesitancy is reduced when the household has access to health information from village health workers.

The decision to get vaccinated involves judgement under uncertainty which requires appropriate weighting of low probability events and various risk scenarios (Tversky and Kahneman, 1974). In the case of COVID-19 vaccination, two risk scenarios are dominant, whereby people weigh the risk of contracting the disease against the 'manufactured risk' due to side effects of the vaccine. Several studies have established that contemporary societies are skeptical about the intentions of government, industries (including pharmaceutical) and scientists and deem them to conspire against the public (Beck, 1992; Douglas and Wildavsky, 1982; Giddens, 1991; Larson et al., 2011; Sherlaw and Raude, 2013). This results in the majority weighting the latter risk higher than the former thereby preferring to eliminate the 'manufactured risk' and maintain the status quo (Samuelson and Zeckhauser, 1988; Thaler, 1980). The propensity to follow the herd, or comfort in numbers in vaccine hesitancy tends to drop if the household perceive itself to be at

high risk of contracting the disease (Abdulkareem et al., 2020). If household perceived vulnerability is high due to among other factors, personal experiences and similarity in characteristics with those getting infected, they are likely to trust scientific information from qualified personnel such as health professionals more than following the herd that is hesitant to get vaccinated (Ning et al., 2020). Several studies have established a high level of correlation between perceived risk of contracting a disease and the adoption of precautionary or preventative health behaviors such as getting vaccinated (Dryhurst et al., 2020; Ning et al., 2020; Wise et al., 2020). This leads us to our third hypothesis linking the risk of contracting COVID-19, access to health information and herding behavior in vaccine hesitancy.

Hypothesis 3. The high perceived risk of contracting COVID-19 in households increases the effectiveness of health information from village health workers in reducing herding behavior in vaccine hesitancy.

3. Methodology

3.1. Study setting

The Zimbabwe COVID-19 vaccination program began in earnest on the February 22, 2021 with the initial 200,000 Sinopharm vaccine doses donated by the government of the People's Republic of China (Ministry of Health and Child Care [MoHCC], 2021a). The aim was to vaccinate 10 million people out of the estimated population of over 15 million (World Population Review, 2021) by the end of 2021 to achieve at least 60% herd immunity (MoHCC, 2021b). The vaccines that have been administered through the public health system are mainly the BBIBP-CorV vaccine known as the Sinopharm vaccine, and the Sinovac vaccine which both originates from the People's Republic of China, Covaxin from India, and Sputnik V from Russia (MoHCC, 2021b; 2021c). Since the vaccines were received in batches of few doses at a time, the vaccination process was staggered following a systematic arrangement informed by the level of risk faced by various workers groups and members of society (MoHCC, 2021a). Frontline workers who are mostly public health officials, were targeted for the initial round of vaccination. The second round of vaccinations targeted teachers, the security sector, the judiciary, and other government officials over and above the frontline workers with the government aiming to open the economy following a series of debilitating lockdowns and stay at home orders that were instituted to contain the spread of the disease. Within the second batch, the government program also targeted vaccinating the elderly and chronically-ill members of society who were deemed to be at a higher risk of fatality in the event of COVID-19 infection (MoHCC, 2021c). As more and more vaccines were received, the vaccination program was opened up for the generality of the public who were willing to be vaccinated, mainly in cities and towns which had recorded the highest rates of infections and acted as hotspots for the spread of the disease across the rest of the country. By the time we started data collection for this study, on the May 3, 2021, the national COVID-19 vaccination program had been opened to include rural areas and at least 300,000 people had received their first vaccine dose (MoHCC, 2021d). By the May 28, 2021, over 650,000 Zimbabweans had received their first dose of vaccine and about 320,000 had received their second shot (MoHCC, 2021d).

Very little is known about COVID-19 vaccine hesitancy in rural Zimbabwe. Due to the geographic makeup, relatively retarded level of information flow and stronger social, religious and cultural ties in rural areas in Zimbabwe, herding behavior is likely stronger as a catalyst in the formation of vaccine hesitancy clusters. To dispel the myths around the COVID-19 vaccine and facilitate transmission of information to the rural population which comprises mostly the elderly, the government of Zimbabwe contracted the services of village health workers. Village health workers are trained health personnel who reside in the villages and the majority of them also grew up in the same communities. They maintain day to day interaction with communities and are available on call. It has been established that these village health workers are trusted and obeyed by their communities due to both the close kinship developed over several years and specialised training they obtained from health authorities which puts them at an information advantage over the rest of the population (UNICEF Zimbabwe, 2021a; 2021b). In other countries such as India, primary health care which includes contracting village health workers has been rolled out at a national level and has been argued to increase health access among the poorest members of society such as the elderly so as to increase universal health coverage (see e.g. Lahariya, 2020).

3.2. Sample generation process

We use nationally representative household data on rural livelihoods from the 2021 cross-section survey that we conducted through the Zimbabwe Vulnerability Assessment Committee (ZimVAC). During the 2021 ZimVAC rural livelihoods assessment, national supervisors and enumerators were recruited from Government Ministries/departments, United Nations and Non-Governmental Organizations and underwent a virtually organized 2-day training exercise in all aspects of the rural livelihoods assessment. Infection Prevention and Control (IPC) measures were employed by enumerators to prevent the transmission of the COVID-19 virus during data collection. Data collection took place from the 3rd to the 20th of May 2021. The ZimVAC study is an annual event which involves several arms of the Zimbabwean Government. Ethical approval for the study was awarded at inception of the programme though the national ethics committee of the Research Council of Zimbabwe (RCZ). Studies that involve government departments and were previously awarded ethical approval by the RCZ are not required to seek the same in subsequent years. Any updates that may be necessary are dispatched and actioned through the government departments in consultation with partners.

3.3. Sample

The sample was drawn using cluster sampling and simple random sampling methods. Firstly, from each of the 60 rural districts in Zimbabwe, we randomly selected 25 enumeration areas (clusters) per district. The second stage involved simple random sampling of 10 households from each of the 25 clusters in each district. All interviews were conducted physically across the country. The interviews were conducted in the mother tongue of the interviewee who is a household member and knowledgeable about all household issues. A total of 15,000 rural households were interviewed using the sampling frame that we described. After data cleaning, we remained with 13, 583 valid observations.

3.4. Description of key variables

We measure household *i's* vaccine hesitancy, $Y_i \varepsilon \{0,1\}$ on the basis of the question "*Are the people in your household willing to receive the COVID-19 vaccine?*". Y_i therefore takes the value of 1 if the response to the question is negative, in which case the household *i* is taken to be hesitant to take the COVID-19 vaccine, and 0 otherwise.

Household *i* perceives itself to be at risk of contracting COVID-19, $R_i \varepsilon \{0,1\}$, if the household answered affirmative to the question "*Do you think anyone in your household is at high risk of contracting COVID-19?*".

We take the household to have access to health information from village health workers, $V_i \varepsilon \{0,1\}$, if the household answers affirmative to the question "*Does your household have access to a village health worker?*".

For each household, *i,* its social network of vaccine hesitant households that it can imitate, $H_i \geq 0$, is simply the summation of the inverse of the distance of each vaccine hesitant household within the 10 km

radius of household *i*. We take the inverse of the distance since we perceive that the further away household *j* is from household *i*, the less likely it is that the decision of household *j* influences household *i*.

3.5. Econometric estimation process

In some empirical studies on vaccine hesitancy, the household vaccine hesitancy $Y_i \varepsilon \{0,1\}$, is explained by the household's characteristics, $\mathbf{X_i}$, without taking into account the vaccine hesitancy externalities that exist amongst the households (e.g., Browne et al., 2015; Prislin et al., 1998; Smith et al., 2011). Our study extends such analyses to cover the existence of vaccine hesitancy externalities or herding behavior amongst households. The major identification problem is to isolate herding from other social interaction effects that might bring about similar effects such as the exogenous effects. According to Manski (1993), a group of individuals with similar exogenous characteristics may behave similarly even if there is no herding behavior, or influence from other individuals in the same group. To isolate herding behavior from the effects of exogenous characteristics it is important to control for the possible effects of such characteristics of the network of the household as emphasized by Matuschke and Qaim (2009). In this study vaccine hesitancy by household *i*, Y_i, is expected to depend on the household own background characteristics, $\mathbf{X_i}$, access to health information from village health workers, V_i, household risk perception of contracting COVID-19, R_i, the distance weighted number of vaccine hesitant households within the household i's locality, H_i, a vector of the average control variables of the distance weighted number of vaccine hesitant households within the household i's locality, $X_{h(i)}$, and the error term, ε_i that is:

$$Y_i = \alpha + \beta H_i + \tau V_i + \varpi R_i + X_i^{'} + X_{h(i)}^{'}\delta + \varepsilon_i \quad (1)$$

β captures the herding behaviors, that is the impact of the distance weighted vaccine hesitant neighbours on vaccine hesitancy propensity of household *i*. δ captures the exogenous effects, that is the effects that the characteristics of the distance weighted vaccine hesitant network members have on household i's vaccine hesitancy. τ shows the average effect of health information from village health workers on the household's vaccine hesitancy. ϖ reveals the average effect of household perceived risk of contracting COVID-19 on the household's vaccine hesitancy. We estimate Equation (1) using OLS and present the results in Table 4. We also show the probit and logit estimation results for robustness. The results in Table 4 speak to Hypothesis 1 of this paper.

To test Hypothesis 2 of this paper which speaks to whether access to health information from village health workers reduce herding behavior in vaccine hesitancy, we follow Wooldridge (2010) by estimating Equation (1) when $V_i = 0$ and when $V_i = 1$ separately and evaluate the t-statistic of the difference in coefficients of the herding effects as follows:

$$t_{V1-V0} = \frac{\beta_{V1} - \beta_{V0}}{\sigma_{V1-V0}} = \frac{\beta_{V1} - \beta_{V0}}{\sqrt{\sigma_{V1}^2 + \sigma_{V0}^2}} \quad (2)$$

Where β_{Vi} is the coefficient of the herding behavior variable, H_i, when the household has access to health information from village health workers, $V_i = 1$ and when it does not $V_i = 0$. σ_{Vi} is the standard error corresponding to the coefficient of the herding variable, H_i, when the household has access to health information from village health workers $V_i = 1$ and when it does not $V_i = 0$. We present the results in Column (III) of Table 5.

Similarly, we evaluate Hypothesis 3 by estimating the coefficient of herding behavior for each value of $V_i \varepsilon \{0, 1\}$ when $R_i = 0$ and when $R_i = 1$ and evaluate the t-statistic of the difference in coefficients as in Equation (2) and present the results in Column (III) of Table 6.

4. Results and discussion

4.1. Descriptive analysis

4.1.1. Background characteristics by access to health information from village health workers

Table 1 shows the background characteristics of rural households in Zimbabwe by access to health information from village health workers. The table shows that access to health information from village health workers in rural Zimbabwe is 86.7%. Households that have access to health information village health workers tend to be male headed, older, and married and living together with their spouse than those that do not have access to health information from village health workers. Furthermore, whilst there are generally no education or income differences in access to health information from village health workers, larger households are more likely to have access to health information from village health workers before controlling for observed confounders.

4.1.2. Social network of vaccine hesitant households

Table 2 shows that households that have access to health information from village health workers have a smaller network of distance weighted vaccine hesitant households within their vicinity than those that do not. The difference in the distance weighted number of vaccine hesitant households within the household's vicinity is 0.036 which is statistically significant at the 1% level of significance before controlling for observed confounders. When one considers the characteristics of the network of vaccine hesitant households for households that have access to health information from village health workers, they tend to be older, less educated, and have larger household sizes than those that do not have access to health information from village health workers.

Table 1
Background characteristics by access health information from village health workers.

	Household has access to health information from village health workers?				Difference in means [Y–N]
	Yes [Y]		No [N]		
	Mean	S.D	Mean	S.D	
Observations # (%)	11,769	(86.7%)	1814	(13.3%)	
Household head is female	0.350	0.477	0.381	0.486	−0.031**
Age of household head [Years]	52.102	17.993	50.881	19.738	1.221**
Married living together	0.620	0.485	0.578	0.494	0.042***
Married living apart	0.072	0.259	0.077	0.267	−0.005
Divorced/separated	0.052	0.223	0.062	0.241	−0.010
Widow/widower	0.229	0.420	0.237	0.425	−0.008
Primary level	0.385	0.487	0.357	0.479	0.028**
ZJC level	0.149	0.356	0.148	0.355	0.000
O' level	0.298	0.457	0.292	0.455	0.006
A' level	0.009	0.095	0.013	0.115	−0.004
Diploma/Certificate after primary	0.004	0.064	0.006	0.075	−0.001
Diploma/Certificate after secondary	0.008	0.088	0.008	0.091	−0.001
Graduate/Post-Graduate	0.004	0.063	0.006	0.075	−0.002
Household size	4.421	2.059	3.929	2.111	0.492***
Income [ZWL]	13,235	97,093	12,261	63,058	974
Mash Central	0.147	0.354	0.076	0.265	0.071***
Mash East	0.153	0.360	0.192	0.394	−0.039***
Mash West	0.108	0.311	0.139	0.347	−0.031***
Mat North	0.115	0.320	0.086	0.280	0.029***
Mat South	0.123	0.328	0.107	0.310	0.015***
Midlands	0.123	0.329	0.218	0.413	−0.095***
Masvingo	0.118	0.322	0.074	0.262	0.044***

Notes: The last column shows the results of two-tailed *t*-test for the difference in the means. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

Table 2
Social network of vaccine hesitant households.

		Household has access to health information from village health workers?				Difference in means [Y–N]
		Yes [Y]		No [N]		
		Mean	S.D	Mean	S.D	
Social network of vaccine hesitant households with the household's vicinity		0.202	0.155	0.237	0.181	−0.036***
Background characteristics of social network of vaccine hesitant households with the household's vicinity:	Household head is female	0.381	0.302	0.379	0.303	0.001
	Age of household head [Years]	51.799	11.884	49.136	12.430	2.662***
	Married living together	0.577	0.309	0.607	0.308	−0.030***
	Married living apart	0.075	0.155	0.072	0.148	0.003
	Divorced/separated	0.060	0.145	0.066	0.153	−0.007
	Widow/widower	0.252	0.273	0.218	0.250	0.034***
	Primary level	0.376	0.302	0.354	0.290	0.022***
	ZJC level	0.136	0.194	0.152	0.211	−0.016***
	O' level	0.289	0.282	0.301	0.275	−0.012
	A' level	0.009	0.055	0.020	0.077	−0.011***
	Diploma/Certificate after primary	0.004	0.046	0.008	0.065	−0.004**
	Diploma/Certificate after secondary	0.005	0.030	0.006	0.044	−0.001
	Graduate/Post-Graduate	0.007	0.054	0.009	0.066	−0.002
	Household size	4.305	1.352	4.212	1.306	0.093***
	Income [ZWL]	8.097	1.498	8.166	1.483	−0.068*

Notes: The last column shows the results of two-tailed *t*-test for the difference in the means. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

4.1.3. Hesitancy to COVID-19 vaccine inoculation

Table 3 shows that the proportion of the rural population that is hesitant to vaccine inoculation is 20.6%. When one considers the sub-population of households that have access to health information from village health workers, 14.7% of households that are at high risk of contracting COVID-19 virus were hesitant to vaccinate versus 23.3% of households that are at low risk. The respective number of vaccine hesitant households goes up when one considers the sub-population of households without access to health information from village health workers, with 23.1% of the households at high risk hesitant to vaccine inoculation versus 36.2% of households at low risk of contracting the COVID-19 virus. Moreover, when one considers the sub-population that perceives itself to be at high risk of contracting COVID-19, having access to health information from village health workers is associated with lower probability that the household is hesitant to get inoculated with COVID-19 vaccines. The same goes, albeit with higher vaccine hesitancy when one considers the sub-sample of households that are at low risk of contracting the virus. The major take from the table is therefore that before controlling for observed confounders high risk and access to health information from village health workers are associated with lower probability that the household is hesitant to COVID-19 vaccination.

Table 3
Hesitancy to COVID-19 vaccine inoculation.

		Household is at risk?		Difference
		Yes [Y]	No [N]	[Y–N]
Overall vaccine hesitancy		0.206		
Vaccine hesitancy when a household has access to health information from village health workers?	Yes [Y]	0.147	0.233	−0.085***
	No [N]	0.231	0.362	−0.130***
Difference	[Y–N]	−0.084***	−0.129***	

Notes: The last row and column show the results of two-tailed *t*-test for the difference in the means. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

Table 4
Herding behavior in COVID-19 vaccine hesitancy.

VARIABLES	OLS	Probit	Logit
	(I)	(II)	(III)
Social network of vaccine hesitant households that it can imitate	0.612***	1.958***	3.309***
	(0.0293)	(0.0945)	(0.161)
Observations	11,918	11,918	11,918
R-squared/Pseudo R-squared	0.086	0.0794	0.0796

Notes: The results control for both household characteristics (presented in Table 1) and exogenous effects (Presented in Table 2). Robust standard errors in parentheses. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

Table 5
Herding behavior in vaccine hesitancy by access to health information from village health workers.

VARIABLES	Household has access to health information from village health workers?		Difference in coefficients
	Yes [Y]	No [N]	[Y–N]
OLS	0.551***	0.870***	−0.319***
	(0.0321)	(0.0746)	(0.0812)
Probit	1.824***	2.562***	−0.738***
	(0.105)	(0.237)	(0.2592)
Logit	3.097***	4.268***	−1.171***
	(0.179)	(0.410)	(0.4474)
Observations	10,347	1571	
R-squared	0.066	0.170	

Notes: The results control for both household characteristics (presented in Table 1) and exogenous effects (Presented in Table 2). Robust standard errors in parentheses. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

4.2. Econometric estimation results

4.2.1. Herding behavior in COVID-19 vaccine hesitancy

Consistent with Hypothesis 1 of this study, OLS estimates in Column (I) of Table 4 shows that an increase in the social network of vaccine hesitant households increases the probability that the household is

Table 6
Impact of access to health information from village health workers on herding behavior by household risk perception.

			Household has access to health information from village health workers?		Difference in coefficients
			Yes [Y]	No [N]	[Y–N]
OLS	Household is at risk?	Yes [Y]	0.484*** (0.0457)	0.848*** (0.119)	−0.364*** (0.1275)
		No [N]	0.581*** (0.0454)	0.854*** (0.0983)	−0.273*** (0.1083)
	Difference in coefficients	[Y–N]	−0.097 (0.0644)	−0.006 (0.1544)	
Probit	Household is at risk?	Yes [Y]	1.773*** (0.161)	2.758*** (0.409)	−0.985*** (0.4395)
		No [N]	1.815*** (0.140)	2.441*** (0.297)	−0.626** (0.328)
	Difference in coefficients	[Y–N]	−0.042 (0.21336)	0.317 (0.5055)	
Logit	Household is at risk?	Yes [Y]	3.087*** (0.283)	4.718*** (0.750)	−1.631*** (0.8016)
		No [N]	3.040*** (0.234)	3.997*** (0.499)	−0.957** (0.5511)
	Difference in coefficients	[Y–N]	0.047 (0.36721)	0.721 (0.9008)	

Notes: The results control for both household characteristics (presented in Table 1) and exogenous effects (Presented in Table 2). Robust standard errors in parentheses. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

hesitant to COVID-19 inoculation *ceteris paribus*. The finding in Column (I) therefore confirms Hypothesis 1 of this study that household propensity to be vaccine hesitant increases with the number of vaccine hesitant households within its social network. The finding is consistent with earlier findings such as Bauch (2005), Bhattacharyya and Bauch (2011), Maurer et al. (2010) Fu et al. (2011) and Smith et al. (2011) amongst others who find that agents mimic vaccine hesitancy decisions of other agents in their social networks indicating herding behavior. The probit and logit estimates presented in Columns (II) and (III) confirm the OLS estimates in Column (I).

4.2.2. Moderating role of access to health information from village health workers in herding behavior in vaccine hesitancy

Table 5 shows the difference in the impact of herding behavior on the probability that the household is hesitant to COVID-19 vaccine inoculation by access to health information from village health workers. OLS estimates in Column (I) of the table shows that when households have access to health information from village health workers, the herding effects are 0.551 whereas Column (II) shows them to be 0.870 when households do not have access to health information from village health workers. The difference in coefficients shown in Column (III) of the table of −0.319 is statistically valid at the 1% level of significance. The findings in the table therefore show that access to the health information from village health workers reduces herding behavior in COVID-19 vaccine hesitancy and confirms Hypothesis 2 of this study that Household's propensity to follow the herd in vaccine hesitancy is reduced when the household has access to health information from village health workers. Probit and logit estimates presented in the Table confirm the OLS results. The findings are confirmed by earlier studies such as Hak et al. (2005) and Yaqub et al. (2014) which found that access to information on vaccines provided by the health professionals increased the probability that the households accept vaccine inoculation.

4.2.3. Impact of access to health information from village health workers on herding behavior by household risk perception

Table 6 shows access to health information from village health workers heterogeneity in herding behavior in COVID-19 vaccine hesitancy under high and low household risk perceptions. Column (III) of the table shows that when considering only households that perceive themselves to be at high risk of contracting COVID-19, herding behavior of COVID-19 vaccine inoculation hesitancy is reduced by 0.364 between those with access to information from village health workers versus those without. On the other hand, when considering only those households that do not perceive themselves to be at high risk of contracting COVID-19, herding behavior is reduced by 0.273 between the respective groups. The findings in the table indicate that whilst access to health information from village health workers reduces herding behavior in vaccine hesitancy, the reduction is amplified for households that perceive themselves to be at high risk of contracting COVID-19 and confirms Hypothesis 3 of this study which states that the high perceived risk of contracting COVID-19 in households increases the effectiveness of health information from village health workers in reducing herding behavior in vaccine hesitancy. The findings are in agreement with earlier studies such as Dryhurst et al. (2020), Ning et al. (2020) and Wise et al. (2020) amongst others, who associate high risk of contracting a disease with adoption of precautionary or preventative health behaviors such as getting vaccinated.

5. Conclusions and policy recommendations

On the basis of the 2021 ZimVAC rural livelihoods assessment data, this paper investigated the existence of risk heterogeneity in the role of access to health information from village health workers in reducing herding behavior in COVID-19 vaccine hesitancy. Our findings indicate that households mimic each other in vaccine hesitancy which is the evidence of herding behavior. Furthermore, whilst health information reduces herding behavior in vaccine hesitancy, the impact is amplified when the household perceives itself to be at high risk of contracting COVID-19.

Herding behavior in vaccine hesitancy seems to be relatively more probable if individuals perceive themselves to be at higher risk of contracting the virus and have no access to reliable sources of health information on vaccines like village health workers. Our findings point to the need to improve accessibility to trusted health information necessary in the formation of rational individual decisions and weighting of alternative risk exposures which reduces the propensity to follow the herd. Dissemination of health information would increase awareness and knowledge thereby debunking conspiracy theories, misinformation and disinformation and nudge people towards COVID-19 vaccination. Public health campaigns are therefore especially important for the subpopulations that are at high risk of contracting COVID-19.

Econometric identification problems emanating from simultaneity and unobservable variables make empirical analysis of herding behaviors in vaccine hesitancy challenging. We set out to address some of these issues by identifying social networks using GPS data and adjusting for exogenous characteristics of the social network. Despite our best efforts, more research is still required, particularly in rural parts of poor nations to aid better understanding of herding behaviors in vaccine hesitancy in rural settings with weak information markets. This is more so as our paper has established that health information from trusted individuals who have both superior training and historical ties to the community like village health worker's is paramount in reducing the propensity to follow the herd.

Credit author statement

Terrence Kairiza: Conceptualization, Methodology, Formal analysis, Writing- Reviewing and Editing. George Kembo: Data curation, Supervision, Writing- Reviewing and Editing. Lloyd Chigusiwa: Validation, Methodology, Writing- Original draft preparation, Writing- Reviewing and Editing.

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.

Data availability

The authors do not have permission to share data.

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