How Does Culture Affect Vaccination Opinion Dynamics?

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Abstract. This study examines how individuals' cultural background plays a role in their opinion dynamics, using COVID-19 vaccination opinions as an example. We considered the two cultural dimensions of collectivism/individualism and power distance, and conducted multiple simulation experiments by adopting the agent-based modelling. We find that COVID-19 vaccination opinions can be considerably polarised in collectivist societies if the power distance is smaller and authorities are less centralised. This result complements the popular view that cultural collectivism is often associated with a high degree of social consensus. Hopefully, the study will help explain differences in national responses to COVID-19 vaccination programs.

Keywords: Culture, Vaccination, Opinion Dynamics, Agent-Based Modelling.

1   Introduction

Worldwide, vaccination is regarded as an effective measure to contain the Covid-19 virus (Altmann et al., 2020; Habibabadi & Haghighi, 2019). However, not only different countries adopted different vaccination policies, but people in those countries reacted quite differently to vaccination (Leonhardt & Pezzuti, 2022). In some societies, different attitudes towards vaccination have developed into a new source of social polarisation (Luo et al, 2021).

There has been an increasing academic interest in unveiling cultural influence on individual behaviours. With a series of models, Hofstede et al. (2005, 2008, 2012) investigate the influence of each of six cultural dimensions on negotiation, demonstrating that cultural dimensions can shed light on the analysis of human attitudes in different cultural contexts. Roozmand et al. (2011) build a model to show the important role of culture in individuals' decision-making process. In the field of health and illness, the influence of culture on human opinions has also been noticed, including recently in the context of Covid-19. Most recent studies focus on the impact

of culture on Covid spreading (Ibanez & Sisodia, 2022; Salvador et al., 2020; Voegel & Wachsman, 2022) and policy implementation (Kreulen et al., 2022; Lu et al., 2021). A few studies have discussed the role of culture in vaccination (Betsch et al., 2017; Lu, 2023; Luo et al., 2021). However, while most of these studies have shown the correlation between culture and Covid-related issues through questionnaire surveys, they leave the mechanism of culture's impact on individuals' decision-making largely unexplained.

Of the six cultural dimensions categorised by Hofstede (2010), we focus on two for our work: individualism/collectivism (IDV) and power distance (PDI), as these are seemingly most relevant in the Covid context(Loïs & Frank, 2018; Lu et al., 2021). Collectivism–individualism is recognised as the most established cultural dimension, reflecting differences in how individuals value independence in relation to their social groups (Triandis, H. C., 2018; Shavitt & Barnes, 2019). In the context of epidemics, vaccination is not only a personal decision, but also a decision involving group interests. Betsch et al. (2017) suggests that the degree of collectivism is at least partially responsible for the differences of vaccination opinions between countries. On the other hand, power distance measures the extent to which the less powerful members of institutions expect and accept that power is distributed unequally, which has to do with authority. (Hofstede et al., 2010). In terms of COVID-19, individuals from a high power distance culture tend to believe that authorities are credible, especially when they are from a higher social rank such as government officials or scientists. Our previous work also shows, at least in a theoretical sense, authorities function as opinion leaders that play a critical role in shaping social vaccination opinions (Li & Jager, 2023), which is related to the dimension of power distance.

Previous research suggests that collectivist societies would do better in coping with pandemics than individualistic societies. For example, collectivism predicts a lower number of deaths (Ibanez & Sisodia, 2022), limiting the spread of the virus (Kreulen et al., 2022), and more mask usage (Lu et al., 2021) than individualism during the Covid pandemic. With regard to vaccination, collectivism predicts higher positive intentions (Betsch et al., 2017; Leonhardt & Pezzuti, 2022). People in collectivist societies are ready to tolerate personal inconvenience to observe prevention policies just because it is good for the community. These studies indicate that collectivist societies would be likely to reach a consensus and see a lower degree of opinion polarisation compared to individualistic societies in terms of Covid.

We argue, however, it can be more complex than these studies and observations suggest. Suppose all the people are willing to follow the decisions made by the highest authority, policy implementation will be simple. There will be a successful compulsory vaccination program and society-wide pro-vaccination norms. Here powerful people are more respected and obeyed and less powerful people expect to be told, then it is a society of large power distance (Hofstede et al., 2012). However, if a collectivist society is also an egalitarian society (low power distance), things would become different, because people will then not just be affected by the administration alone, but equally by powerful people in their local communities. As a result, social opinions could be diversified and different opinion groups could emerge in different local groups, leading to rival groups with different, sometimes even opposing norms

and therefore, a high degree of social polarisation. When we further consider more than one authority, for example, every local region or subgroup in society has their own local authority, the centralization (all local authorities with similar opinions) and decentralization (all local authorities with different opinions) of structure can contribute to more dynamics.

To explore how different cultures may respond to a pandemic and policies aimed at vaccination, we expand a basic agent-based model (ABM) to explore the evolution of social polarisation emerging from simultaneous interactions between interdependent individuals and groups that are connected by complex social networks and embedded in diverse cultures (Flache et al., 2017; Gilbert & Troitzsch, 2005). Overall, we posit that culture shapes individuals' opinion towards vaccination to some extent and helps explain regional differences in opinion polarisation. This study provides a dynamic and cultural perspective on Covid-19 vaccination opinion formation based on Hofstede's cultural dimensions theory (Hofstede et al., 2010), especially two dimensions - collectivism and individualism (IDV) and power distance (PDI). We try to answer some questions such as, what role do cultures play in individual opinion dynamics? And how do individuals respond to social influences from authority and peers based on their culture?

2 Theoretical Framework

2.1 Collectivism and social norms

Collectivism measures the tendency to be more concerned with the group's needs, where individuals are interdependent, compared with individualism (Hofstede, 2012). It proposes that adherence to social norms is more important in collectivistic than in individualistic cultures (Suh et al., 1998; Cialdini et al., 1998; Hofstede, 2001; Betsch et al., 2017). In this society, people are more relational and take into account social obligations and group norms when making decisions.   In-group influence, on the one hand, is preferentially considered over out-group. It means, being part of the same group increases the social importance of each other. On the other hand, the strength of social norms between groups can be different, which measures how much are agents willing to have others acting in their behaviours.

2.2 Power distance and authority

In addition to social norms, authoritative pressure is a factor that cannot be ignored in the dynamics of individual opinion, particularly in dealing with Covid-related policies. To reflect this fact, we define authorities as a special type of agents who have more power than ordinary individuals and whose opinions are more fixed than others. The definition of authority we use is similar to that in opinion dynamics and social influence literature (e.g., Suo & Chen, 2008; Heinke et al., 2013; Cremonini & Maghool, 2020), though instead of "authority", also other names are being used for the similar concept, such as "expert" (Quattrociocchi et al., 2011), "opinion leader" (Van Eck et al., 2011; Moldovan et al., 2017), and "hub" (Manzo & van de Rijt,

2020). Authority plays a critical role in shaping social attitudes (Katz, 1957; Van Eck et al., 2011), which has not yet been thoroughly studied in the field of epidemics and vaccination.

Power distance is related to power structures and interactions carried out by the authority. It is a cultural reflection of the degree to which individuals should obey the instructions of the authority. Individuals from a culture of high power distance are expected to form their opinions dependent more on authority than a culture of low power distance. In this sense, power distance can be seen as an amplifier of authority influence on personal opinions.

2.3   Centralization and decentralization

Another relevant factor is the centralization and decentralization (Hage & Aiken, 1967) of power among authorities. Centralization refers to the concentration of power at a top level of a system, where lower-level authorities have limited influence and just need to follow the top authority. Decentralization   refers to the dispersal of power throughout various authorities, with an emphasis on the even and systematic distribution of power.   Some studies have shown that centralization of authorities can achieve higher performance and efficiency especially in simpler environments (Godfray et al., 2010; Kurt et al., 2022). Some, however, argue that centralization can be less robust to sudden system overloads, whereas a decentralized power structure is desirable because it is inherently more stable and resilient (Dahlberg, 2008; Pierpaolo et al., 2017). The uncertainty of the impact of authority centralization on the system has been proved by previous research. We adopt this variable to increase the dynamics of the opinions, which may produce more interesting results.

Following the above theoretical foundation, we propose a set of intuitions that guide the design of our simulation experiments. First, previous work leads to the intuition that collectivism promotes opinion consensus. It is conceivable that in a connected network, everyone actively follows the group norms, then opinions agreed by the majority of the group (such as supporting vaccination) are more likely to be accepted and spread. And the higher the level of collectivism, the more likely this opinion becomes the prevalent opinion.

Intuition 1. Collectivism predicts more opinion consensus than individualism.

Second, our earlier work (Li & Jager, 2023) has shown that authority plays a vital role in the distribution of opinions among the population. In a society with a high power distance, we could expect most people to follow government norms, regardless of their initial opinions. Therefore, the higher the power distance, the easier it is for the government's opinion to become the general opinion of the population.

Intuition 2. Higher power distance predicts more opinion consensus than lower power distance when there is only one authority.

Third, our work (Li & Jager, 2023) also demonstrates that when there is only one pro-vaccine authority, social opinions tend to focus on the pro-vaccination consensus, while when there are two authorities with opposing opinions, the individuals ' opinions are most polarised. However, more authorities with a moderate position reduces the polarisation in society, which is related to decentralization. Then we get the Intuition 3.

Intuition 3. Centralization predicts opinion consensus more than decentralization.

3   The Model

The overall purpose of the model is to clarify the opinion dynamics of public opinion across different cultural dimensions. Specifically, we want to explore how individualism, power distance, and the role of authority contribute to opinion clustering.

The main elements of the model are as follows. There are N individuals in a random network. The average degree of networks, f, determines the number of friends who influence an individual's opinion. A larger f indicates a denser network. There are N_a authorities who are connected to M_a other individuals. Each individual has a random opinion, $O_i \in [0, 1]$. Individuals update their opinions by interacting with friends and authorities with whom they are connected. Interactions between individuals and authorities are based on the weight of the link, w, and their opinion difference, d. The specific individual opinion update is calculated by the following functions:

$$O_{it+1} = O_{it} + \frac{\mu}{N+Na}\left(\sum_{a=1}^{Na} w_{iat}^{a}\left(O_{at} - O_{it}\right) + \sum_{j=1}^{N} w_{ijt}^{p}(O_{jt} - O_{it})\right)$$

$$w_{ijt} = f(idv, d) = \begin{cases} \left(\frac{t-d}{t}\right)^{2*idv}, d < t \\ -\left(\frac{d-t}{1-t}\right)^{2*idv}, d \geq t \end{cases}$$

$$w_{iat} = f(pdi, d) = \begin{cases} \left(\frac{t-d}{t}\right)^{1/2pdi}, d < t \\ -\left(\frac{d-t}{1-t}\right)^{1/2*pdi}, d \geq t \end{cases}$$

Where,

μ is the maximum rate of change (typically is 0.5);

w_{iata} is the weight on the influence of authority, which is a function of power distance (pdi) and ego-authority opinion difference (d_{ia});

w_{ijtp} is the weight on the influence of peers, which is a function of collectivism (idv) and ego-peer opinion difference (d_{ij});

pdi and *d_{ia}* influence weight in opposite directions, while *idv* and *d_{ij}* influence weight in similar directions;

it sets the position of the threshold where positive influence turns into negative influence.

Table 1: Parameters used in the model.

Parameter	Description	Dynamic	Range
N	The number of individuals	No	Natural number
N_a	The number of authorities	No	Natural number
f	Network degree, describing the density of network connections	No	Natural number
O	The attitudes toward vaccination	Yes	[0, 1]
idv	Level of individualism	No	>= 0
pdi	Level of power distance	No	>= 0
w	The importance of the information source	Yes	[0, 1]
d	The opinion distance	Yes	[0, 1]
t	Threshold of positive influence and negative influence	No	[0, 1]
μ	Maximum degree of change in opinion	No	[0, 1]
m_a	The number of authority links	No	Natural number

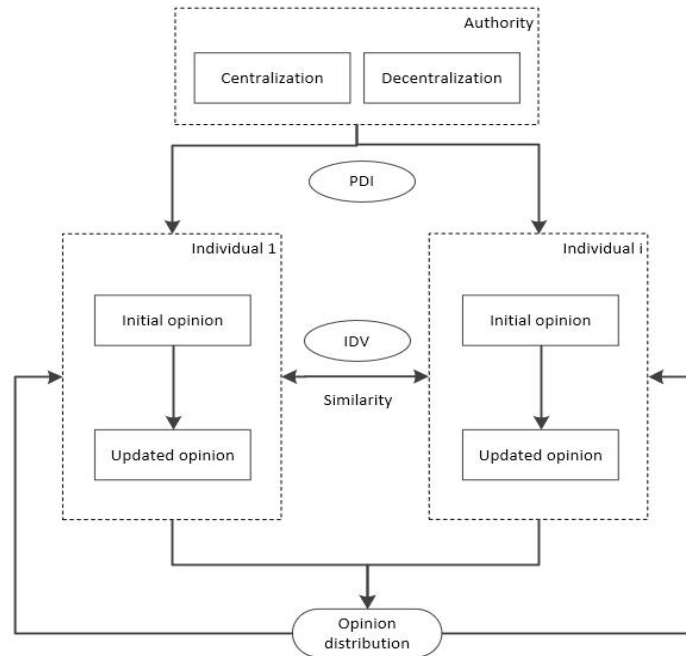The preliminary conceptual framework is shown in **Figure 1**.

Figure 1. A simplified illustration of the model framework.

4   Model Results

Scenario 1: The effect of collectivism on opinion dynamics

We first investigate whether changes in the level of individualism and collectivism affect opinion distribution among people. The initial opinions are randomly distributed. **Figure 2** depicts the evolution of individual opinions for low, medium and high values of *idv*   (= 0.1, 0.5, and 4). It suggests that in a limited time, the lower the *idv*, the faster the opinions converge to middle level. At a lower *idv* of 0.1, opinions are centred around the middle within 100 steps, while more time is needed for the higher *idv*. A high *idv* (= 4) predicts more clustering among individuals, but according to the model, given enough time, opinions will eventually converge.
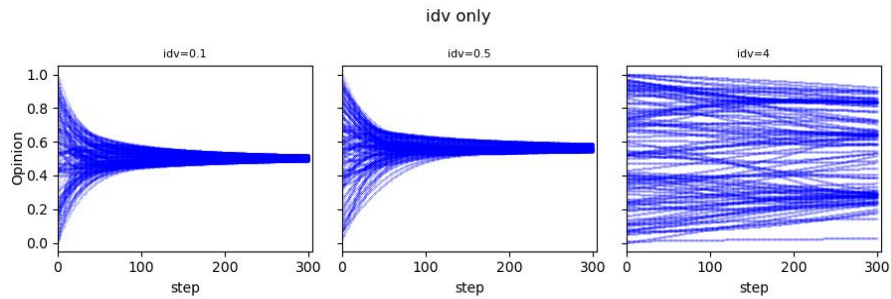
Figure 2 Evolution of opinion distribution under different *idv*.

Scenario 2: The effect of power distance on opinion dynamics

We introduce authorities in this experiment to investigate how they contribute to the resulting opinion distribution. There is only one authority in the model whose opinion is 1, and the opinions of other individuals are randomly distributed between 0 and 1. The influence of authorities on individual opinions is mediated by power distance (*pdi*) and opinion difference.

Figure 3 depicts the opinion distribution for different *pdi* and *idv*. It suggests that when *pdi* is low, the lower the *idv*, the more likely the opinions converge to the middle in the end,   which is similar to **Scenario 1**, except that it takes longer for the opinion to converge.. When *pdi* is high, the lower the *idv*, the more likely the opinions converge to the side of authority's opinion. In general, the pulling effect of high *pdi* on personal opinion towards authoritative opinion was neutralised by high *idv*.
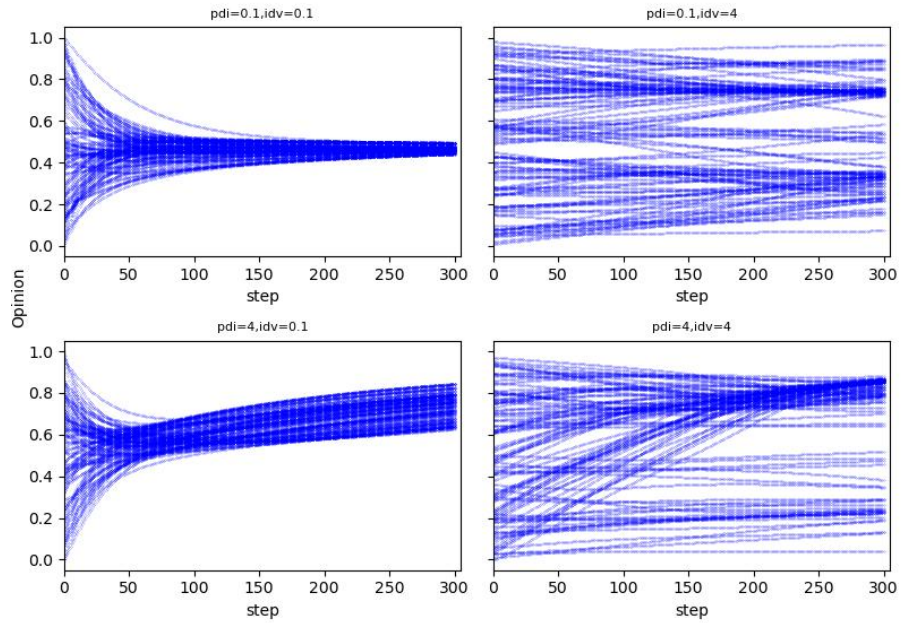
Figure 3 Evolution of opinion distribution for different combinations of *idv* (= 0.1, 4) and *pdi* (= 0.1, 4) when considering centralization (opinions of authorities).

Scenario 3: The effect of decentralization on opinion dynamics

In this scenario, we add more than one authority (for simplicity, 2 authorities) and they have conflicting opinions, representing a decentralised network. **Figure 4** shows similar results to **Scenario 2** when *pdi* is low, but quite different when *pdi* is high. Specifically, when *pdi* is high and *idv* is low, individual opinions tend to be concentrated first and then gradually dispersed. When *pdi* is high and *idv* is also high, individual opinions evolve into distinct clusters.
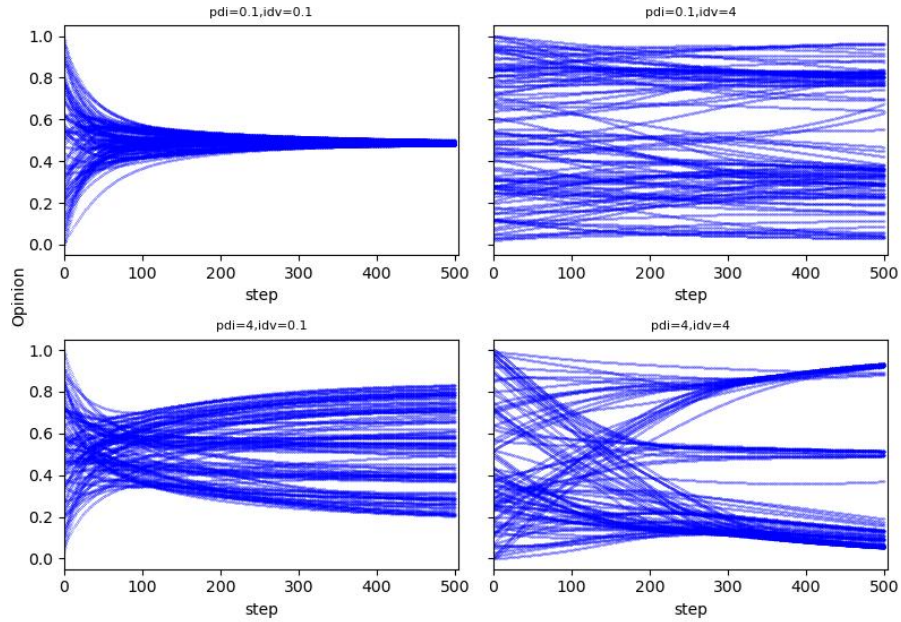
Figure 4 Evolution of opinion distribution for different combinations of *idv* (= 0.1, 4) and *pdi* (= 0.1, 4) when considering decentralization.

Scenario 4: The effect of conflicting initial opinions between individuals and authorities

In this scenario, we further consider the situation in a centralised society with a high power distance (*pdi* = 4), there is a large difference between authority opinions and individual opinions. The initial prevailing opinions of individuals are set to 0, and the initial opinion of all authorities to be 1.

Figure 5 depicts the distribution of individual opinions and clearly shows that societies with higher individualism (*idv* = 4) are more polarised.
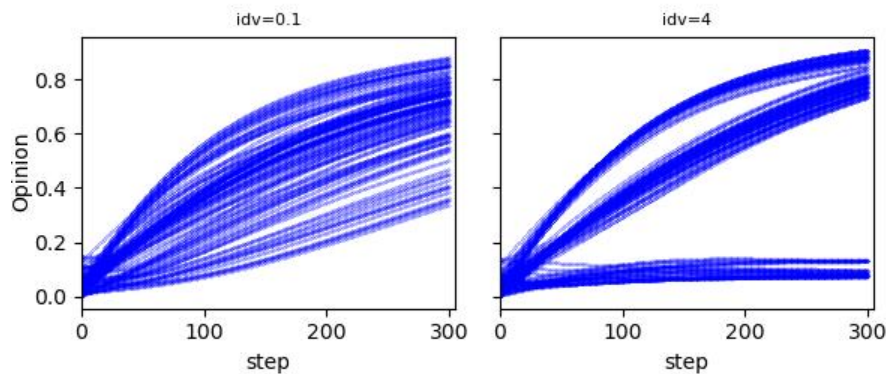
Figure 5 Evolution of opinion in a centralised society with a high power distance (***pdi*** = 4).

5   Conclusion

In this study we have illustrated the important role culture plays in vaccination opinion dynamics. Specifically, we build an agent-based model to explore how the two dimensions of Hofstede's cultural dimensions, individualism/collectivism and power distance, affect individual opinion dynamics, and what kind of macro results could emerge. Previous studies show that collectivism promotes more social consensus than individualism and our simulation results do prove that is true. Nevertheless, we believe the association between collectivism and social consensus is more complex than they suggested. We argue that collectivism does not always promote concentration of opinions, but may lead to polarisation. For example, when considering the role of authority and social networks, we find that authority plays an important role in opinion distribution, which is moderated by power distance. The greater the power distance, the greater the division in society if it is a decentralised network among authorities. These model results can provide explanations for many sociocultural issues, including vaccination decisions.

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