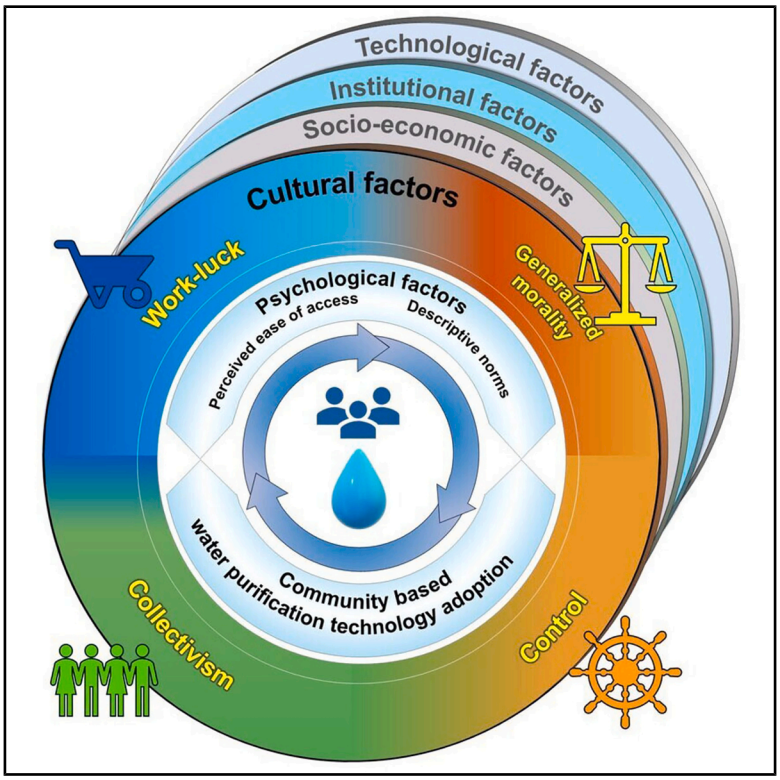
iScience

Article

Cultural dynamics and endogeneity in psychological drivers of adoption of community-based water purification technology in rural India

Graphical abstract



Authors

Mithun Raj, Saket Pande, Maneesha Vinodini Ramesh

Correspondence

maneesha@amrita.edu

In brief

Earth sciences; Environmental science; Environmental issues; Hydrology; Social sciences; Psychology

Highlights

- Endogeneity in psychological factors biases adoption estimates up to 175%
- Cultural traits serve as instruments for endogenous psychological determinants
- Two-stage regression corrects bias from reverse causality in adoption
- Norms and access reinforce the adoption of water purification via feedback

Raj et al., 2025, iScience *28*, 113857
December 19, 2025
https://doi.org/10.1016/j.isci.2025.113857

CellPress

iScience

CellPress
OPEN ACCESS

Article

Cultural dynamics and endogeneity in psychological drivers of adoption of community-based water purification technology in rural India

Mithun Raj,[1] Saket Pande,[2] and Maneesha Vinodini Ramesh[1,3,*]
[1]Amrita School for Sustainable Futures, Amrita Vishwa Vidyapeetham, Amritapuri, India
[2]Department of Water Management, Delft University of Technology, Delft, the Netherlands
[3]Lead contact
*Correspondence: maneesha@amrita.edu
https://doi.org/10.1016/j.isci.2025.113857

SUMMARY

Understanding the behavioral drivers of technology adoption is critical to promoting public health in rural areas, particularly in the context of safe drinking water. This study investigates the psychological determinants of adopting a community-based water purification technology deployed in 300 rural communities. Using a two-stage regression framework, we correct for endogeneity in behavioral models, showing that adoption itself can reshape psychological drivers such as perceived benefits and descriptive norms. Cultural factors, measured through Hofstede's dimensions and World Values Survey constructs, serve as instrumental variables to address reverse causality. Our findings reveal that cultural factors such as generalized morality, belief in hard work, and collectivism indirectly shape adoption behavior by influencing psychological perceptions. These results offer methodological and practical contributions by demonstrating how culturally informed interventions, aligned with community values, can enhance the long-term adoption of water purification initiatives.

INTRODUCTION

Although water covers 71% of the earth's surface, the availability of clean, affordable drinking water remains one of the most pressing global issues as a result of the depletion of fresh water.[1] By 2040, nearly one in four children worldwide is expected to reside in high-water stress areas.[2] This worsens an already critical situation, that as of 2022, about 2 billion people were without access to a safe water supply, contributing to a significant portion of health risks and avoidable deaths.[3] Despite considerable progress toward SDG 6, India is one country that remains water-stressed, particularly in rural areas, where access to clean water remains limited.[4] The implications of these water access problems are massive, which include an estimate that 37.7 million Indians suffer from water-borne diseases each year and 1.5 million children die from diarrhea each year.[5,6]

Community-based water purification technologies play a pivotal role, especially in rural regions, in bridging the gap in access to clean drinking water.[7] Moreover, these technologies are quite relevant for rural India, where the centralized water distribution network is not able to meet the needs of the population.[8] Yet despite their advantages, these community-based purification technologies are not always consistently adopted as the primary source of purified water.[9,10]

The success of such technologies depends not only on technical functionality or infrastructure availability but also on the behavioral and social dynamics that govern their adoption. Several studies have elaborated on psychological and contextual factors explaining the decision to adopt such technologies, emphasizing barriers and drivers that could be useful for targeted interventions aiming to promote the adoption.[11] By making use of established psychological concepts and frameworks, we can better understand why certain communities do or do not adopt water purification technologies. For example, the risk-attitude-norm-ability-self-regulation (RANAS) model[12] focuses on the role of risk perception, personal norms, and self-regulation, while the health belief model (HBM)[13] focuses on how severity and benefits perceptions promote health-related behaviors. The other is the Integrated Behavioral Model for WASH (IBM-WASH),[14] which integrates individual, social, and contextual factors. In this article, we primarily utilize the theory of change (ToC) proposed more recently[11] as the framework outlines the psychological determinants and contextual factors of the adoption of decentralized water treatment technologies (see Figure 1). Some of the key ToC determinants are perceived vulnerability and severity to water-borne diseases, perceived costs, and benefits, e.g., cost-effectiveness and ease of access, and social norms. All of these factors play a significant role in shaping the community's acceptance behavior toward adopting them.[11,15–18] For example, when people believe they can easily access purified water and view the technology as affordable and financially sustainable over the long term, they are more likely to adopt it.

The challenge of endogeneity

Technology adoption is not a one-way process. In turn, it can also affect psychological factors or perceptions that are presumed to

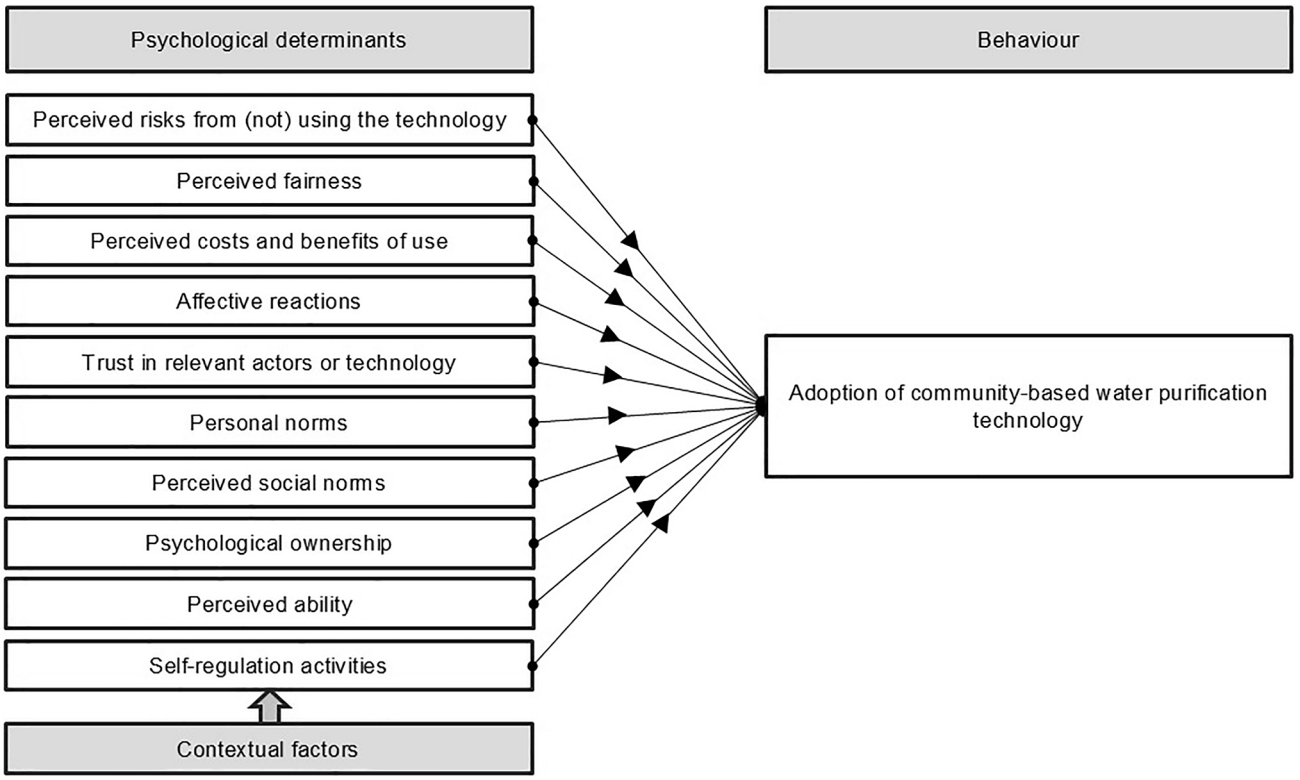


Figure 1. ToC, mapping potential pathways to the adoption of community-based water purification technology
Figure adapted with permission from.[11]

drive it.[19] For example, in many studies social norm is viewed as a one directional predictor that predicts technology use by the assumption of its influence.[20] Alternatively, community members who adopt water purification technologies can also create and strengthen social norms within their community to support further adoption.[21] It demonstrates a bidirectional feedback loop between psychological predictors and technology adoption behavior of water purification technologies. These interrelated connections highlight the complexity of social impact and changing behavior. It also indicates that well-established behaviors can evolve and can change the norms of communities over time.[22]

The adoption of community-based water purification technologies is often studied through regression analyses, where psychological factors serve as independent variables and adoption is treated as the dependent variable. These methods, however, usually assume that errors in the dependent variable are unrelated to the outcome variables. This assumption may not always hold true in behavioral studies. Correlations can arise from the endogeneity of independent variables. Such endogeneity can occur due to reverse causality, e.g., when the adoption of community purification technologies impacts the psychological factors and perceptions within the community[19,20]

Endogeneity is a common issue in empirical research, particularly in fields such as business, management, and WASH-related behavior studies, where feedback loops between psychological, social, and resource factors can bias causal estimates. This bias can distort the true effect of independent variables on the dependent variable, resulting in misleading interpretations, particularly when studying water use behavior explained by psychological factors. Therefore, controlling for endogeneity is crucial to produce reliable inferences, especially when investigating how perceptions and beliefs influence real-world decisions such as the adoption of community-based water purification technologies.

Objectives and contributions to the study

To address the methodological challenge of endogeneity in behavioral adoption research, this study adopts a two-stage regression approach in which potentially endogenous psychological variables are first predicted using cultural traits as instrumental variables (IVs). Culture has long been recognized as a key foundation for understanding psychological processes and behavior.[23] We use cultural traits, such as trust, individualism, and beliefs about control or effort, as instrumental variables (IVs). These traits, sourced from frameworks such as the World Values Survey and Hofstede's dimensions, are theoretically exogenous and temporally stable. Cultural factors, being slow-moving and stable over time, indirectly influence technology adoption through their effects on psychological factors such as perceived norms or self-efficacy but do not directly influence adoption (see Figure 2). This satisfies the conditions for valid instruments, allowing us to isolate the causal effect of psychological factors on the adoption of water purification technologies, mitigating the bias introduced by reverse causality. While the

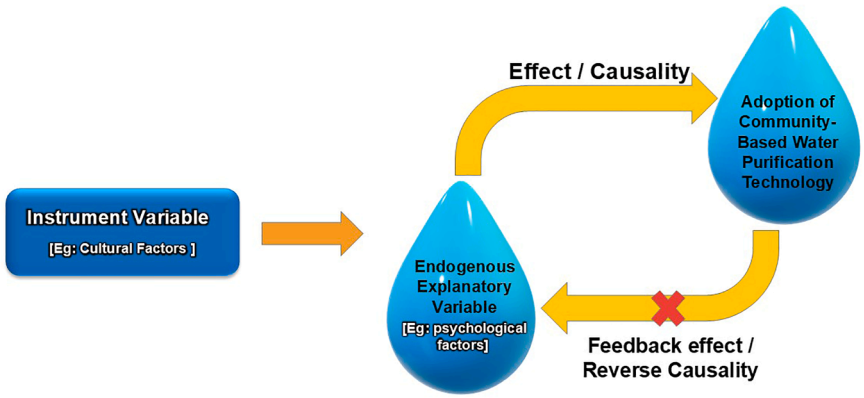


Figure 2. Feedback effect or reverse causality applied to community-based water purification technology adoption behavior

IVs based on cultural factors can break the reverse causality. Image adapted with permission from.[19]

use of IVs in WASH-related behavioral studies, particularly in developing countries, remains rare, a few examples exist. For instance,[19,24] incorporated IVs to mitigate endogeneity.

Cultural elements, such as traditions, religious beliefs, and family dynamics, play a crucial role in shaping psychological processes and behaviors, indirectly impacting technology adoption.[25] The literature review shows that culture has an impact on thought processes, responses, and behaviors by virtue of values and experiences.[26,27] For instance, psychological factors such as perception and attitudes are influenced by cultural norms and social roles, which, in turn, impact consumer behavior.[28] Moreover, traditions and religion as well as the community values that one adheres to, can, in turn, influence how communities value the benefits and usability of a technology.[29]

Previous studies have identified specific cultural traits, shaped by historical contexts, that significantly influence current economic development, utilizing indicators from the World Values Survey (WVS) and Hofstede's cultural dimensions to measure values such as trust, respect for others, and confidence in self-determination.[30,31] These survey questions have been used to represent a broad selection of cultural dimensions, allowing researchers to systematically compare the effects of culture on economic development. For example, beliefs regarding the connection between hard work or luck and success have implications for social mobility and economic development.[30,31] Some argue that success is achieved through hard work, while others believe it has more to do with luck or social connections. These views drive larger economic trends: communities that favor hard work have long stood as the cradle of industrialization and development. Research also links cultural traits such as a limited sense of control over one's life to issues, such as poor entrepreneurship and low literacy rates.[30]

This study builds on such insights by proposing a conceptual pathway in which cultural factors influence psychological factors, which in turn affect adoption behavior: cultural factors => psychological factors => technology adoption. The strong empirical association between culture and psychological determinants makes cultural traits effective instruments for addressing endogeneity in adoption models. The study introduces a novel application of instrumental variable methods to WASH-related behavioral research, where the issue of reverse causality is well-recognized but rarely addressed. By using cultural indicators as instruments, the study evaluates their validity both conceptually and empirically, while also offering new insights into how culture shapes psychological constructs and, through them, community technology adoption decisions. The study, therefore, investigates i) whether psychological factors are endogenous when estimating their impact on the adoption of community-based water purification technology in rural India and ii) the validity of cultural elements as instrumental variables for these endogenous factors, contributing to WASH-related behavioral research through surveys from Indian rural communities.

This study investigates the endogeneity of psychological determinants of the adoption of a specific community-based water purification technology deployed in Indian rural communities, "Jivamritam,"[32] based on the ToC framework laid out by.[11] To the best of our knowledge, no study has specifically addressed the endogeneity effects related to the adoption of community-based water purification technologies in developing countries while considering a broad range of psychological and contextual factors and how culture is mediated in its effect on the adoption of purification technologies. By addressing this gap, the study contributes to strengthening adoption research methods and offers practical insights into WASH interventions.

Jivamritam

Jivamritam is a community-based water purification program launched in Indian communities to address water sustainability challenges by empowering the communities. The program is intended to build the capacities in the communities to identify, measure, map, and monitor water sustainability issues in the communities. Over 10,000 communities in India, facing water quality challenges, were assessed through phased evaluations, leading to the selection of 1,000 communities for the initial implementation phase of the program. Since its inception in 2017, Jivamritam has been deployed in around 300 rural communities[32] (Figure 3 shows 54 rural communities where the study was conducted). The implementation used a multi-stakeholder approach involving the community, Amrita University, NGOs, and the local government. The adoption of Jivamritam followed a phased approach across communities, reflecting a strategy of gradual engagement. In some communities, the initial implementation received strong acceptance and enthusiasm, demonstrating the program's potential impact. In other regions, the focus has been on building community trust and providing additional support. This variability presents a chance to learn and adapt strategies for broader adoption and continuous improvement.

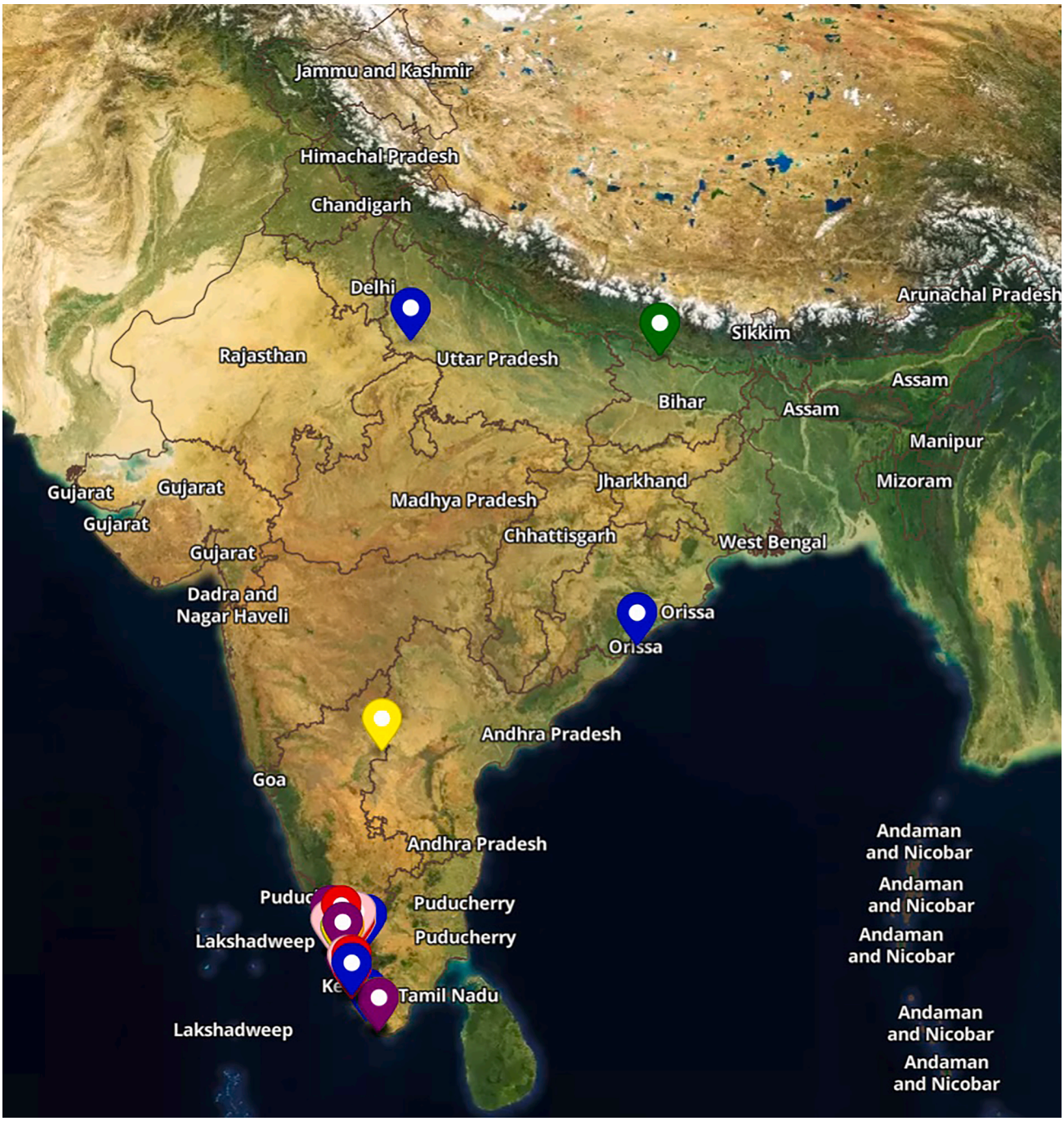


Figure 3. A map highlighting 54 rural communities across India where Jivamritam has been implemented

RESULTS

Descriptive results

Descriptive statistics and correlations for all psychological and contextual variables are presented in the supplemental information (Tables S1 and S2). Table 1 captures the results of the unweighted logistic regression analysis of SEC, contextual, and psychological factors for Jivamritam adoption. Among the significant predictors, we focused on perceived vulnerability, severity, ease of access, cost-effectiveness, and descriptive norms. Although family assistance emerged as a significant contextual factor, it was excluded from further analysis as the focus was solely on psychological determinants. Additionally, we excluded trust in the implementing agency, which is a direct predictor, because our analysis prioritizes cultural factors, such as generalized and political

Table 1. Unweighted logistic regression of SEC, contextual, and psychological factors on Jivamritam adoption (*N* = 906)

Independent variables	Estimate	Std. Error	z value
Perceived Vulnerability	−0.33 *	0.15	−2.14
Perceived Severity	0.37 *	0.18	2.00
Perceived Safety	0.36	0.18	1.93
Perceived good taste	−0.32	0.18	−1.77
Perceived ease of access	0.95 ***	0.22	4.22
Perceived time benefit	−0.24	0.18	−1.26
Perceived cost effectiveness	0.62 ***	0.19	3.43
Perceived ability	0.27	0.19	1.39
Descriptive Norms	0.84 ***	0.17	4.82
Injunctive norms	0.09	0.23	0.39
Distance	−0.54 *	0.27	−2.00
Family members assistance	2.57 **	0.90	2.84
Trust in implementing agency	0.64 **	0.22	2.87
Trust in water committee	0.08	0. 25	0.33
Psychological ownership	0.43	0.25	1.72
SEC	0.07	0.11	0.67
Gender	−0.41	0.27	−1.51
Household size	−0.11	0.09	−1.14

R^2 = 0.66; *p < 0.05. **p < 0.01. ***p < 0.001.

trust, that influence Jivamritam adoption indirectly through psychological factors. This distinction allows us to explore the deeper, culturally driven mechanisms behind adoption behavior, rather than direct institutional trust. The effects of psychological determinants on Jivamritam adoption were estimated using a two-stage regression model that accounts for endogeneity (Figure 4).

Predicting psychological determinants using cultural factors

Tables 2 and 3 show the results of linear regressions between cultural factors and key psychological determinants. When all nine cultural factors were used simultaneously to predict psychological determinants in multiple linear regressions (Table 2), the R^2 values were low for perceived vulnerability and severity

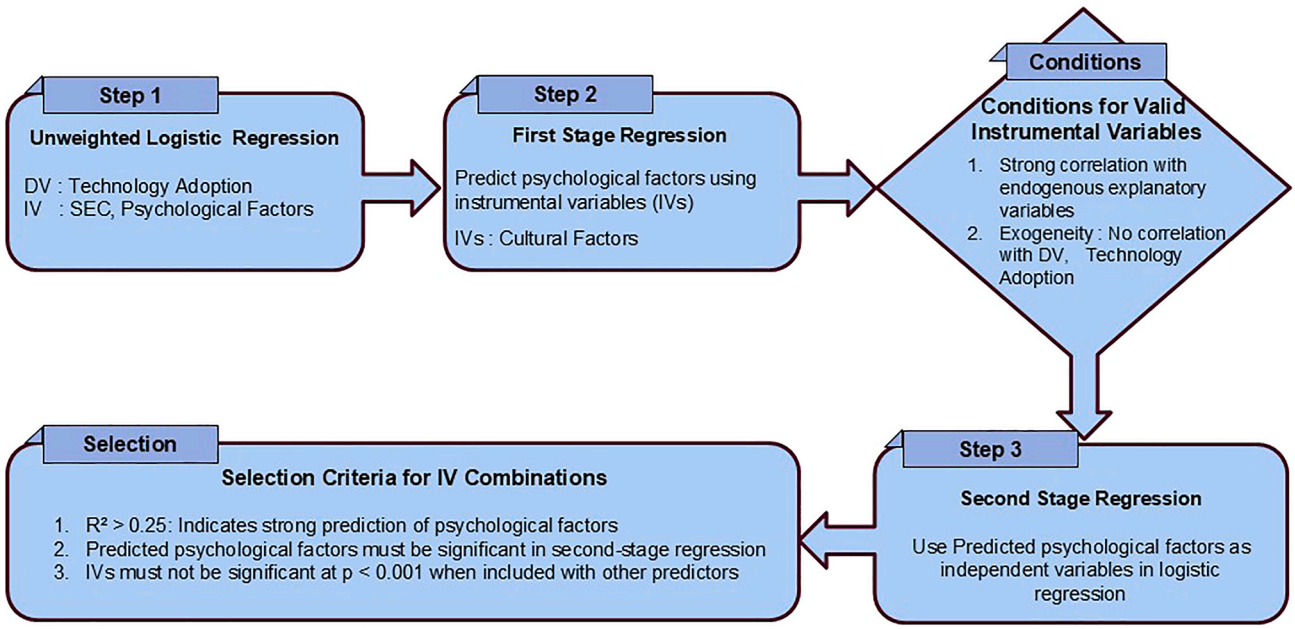


Figure 4. Steps involved in the regression analysis

Table 2. Unweighted multiple linear regression of all cultural factors on ToC factors

Independent variables	Dependent variables				
Cultural Factors	Perceived vulnerability	Perceived severity	Perceived ease of access	Perceived cost effectiveness	Descriptive Norms
Generalized Trust	0.01	0.06	0.32 ***	0.28 ***	0.08
Family ties	0.41 ***	0.19 ***	−0.02	−0.06	0.22 ***
Political Trust (in local government)	0.17 **	0.09 *	0.24 ***	0.22 ***	−0.22 ***
Political Trust (in political parties)	0.05	0.07 *	0.03	0.00	0.49 ***
Control	0.20 *	−0.01	−0.04	−0.02	0.25 *
Work-Luck	0.04	−0.12	−0.05	0.04	−0.06
Generalized Morality	0.71 ***	0.05	0.06	0.32 ***	0.51 ***
Power Distance	0.02	0.00	0.40 ***	0.42 ***	0.22 ***
Individualism-Collectivism	0.31 ***	0.24 ***	0.08	−0.05	0.52 ***
R^2	0.25	0.14	0.67	0.65	0.29

*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

but higher for perceived ease of access, cost-effectiveness, and descriptive norms. Additionally, individual one-to-one regressions between each cultural factor and psychological determinant (Table 3) showed weak correlations with perceived vulnerability, severity, and norms, but stronger correlations with perceived ease of access and cost-effectiveness, yielding an average R^2 of 0.22. These findings indicate two key points: (1) cultural factors are weak instruments for predicting perceived vulnerability and severity, and (2) multiple cultural factors are needed to accurately predict perceived ease of access, cost-effectiveness, and norms, increasing the R^2 between observed and predicted psychological variables. As a result, perceived vulnerability and severity were treated as exogenous in subsequent analyses. Notably, seven cultural factors significantly predicted descriptive norms in multiple regressions (Table 2), and the highest average R^2 values were found for perceived ease of access and cost-effectiveness (Table 3), suggesting that cultural factors are more closely related to descriptive norms and perceived benefits.

Two-stage regression results

To prevent multi-collinearity, various combinations of cultural factors were analyzed that could predict perceived ease of access and descriptive norms using the three criteria mentioned in the previous section. Two combinations were identified that satisfied all three assumptions: (i) generalized morality and individualism-collectivism to predict descriptive norms (R2 = 0.3), (ii) control and work-luck to predict perceived ease of access (R2 = 0.6). The predicted ease of access and norms also showed significant effects in the second-stage regression. (Table 4, column 4). Additionally, the next assumption, a valid instrument was also met (Table 2, column 6). These IVs were not statistically significant at $p < 0.001$ when included in the logistic equation alongside other predictors, i.e., SEC, predicted ease of access, predicted norms, and remaining exogenous psychological variables. The impact of perceived ease of access and norms on the adoption of Jivamritam was significantly underestimated in the standard logistic regression analysis. Coefficients for perceived ease of access and norms were 0.95 and 0.84, respectively. In contrast, the

Table 3. Unweighted multiple linear regression of each cultural factor on ToC factors

Independent variables	Dependent variables				
Cultural Factors	Perceived Vulnerability	Perceived Severity	Perceived ease of access	Perceived Cost effectiveness	Descriptive Norms
Generalized Trust	0.27 ***(0.09)	0.15 ***(0.05)	0.69 ***(0.46)	0.69 ***(0.44)	0.33 ***(0.10)
Family ties	0.48 ***(0.11)	0.28 ***(0.07)	0.34 ***(0.04)	0.31 ***(0.03)	0.41 ***(0.06)
Political Trust (in local government)	0.30 ***(0.11)	0.15 ***(0.05)	0.77 ***(0.53)	0.77 ***(0.50)	−0.32 ***(0.09)
Political Trust (in political parties)	0.27 ***(0.06)	0.16 ***(0.04)	0.67 ***(0.29)	0.65 ***(0.26)	0.52 ***(0.18)
Control	0.42 ***(0.03)	−0.02 (0.00)	0.62 ***(0.04)	0.74 ***(0.06)	0.31 **(0.01)
Work-Luck	0.41 ***(0.02)	−0.04 (0.00)	0.54 ***(0.03)	0.71 ***(0.05)	−0.16 (0.00)
Generalized Morality	0.96 ***(0.09)	0.14 (0.00)	0.83 ***(0.05)	1.11 ***(0.08)	0.74 ***(0.04)
Power Distance	0.25 ***(0.08)	0.14 ***(0.05)	0.72 ***(0.52)	0.73 ***(0.51)	0.34 ***(0.12)
Individualism-Collectivism	0.01 (0.00)	0.16 **(0.01)	−0.52 ***(0.04)	−0.68 ***(0.06)	0.19 *(0.01)
Average_R^2	0.07	0.03	0.22	0.22	0.07

*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$; the value inside parentheses is the individual R^2.

Table 4. Results from various logistic regression analyses for technology adoption: standard regression (without IVs), second-stage regression (considering predicted values of endogenous ToC factors), and for testing the exogeneity assumption for the instrument variables

		Coefficient (β) in Jivamritam adoption for various logistic regressions			
Variable Category	Variable Name	Standard regression (without IVs)	Second-stage regression (without residuals)	Second-stage regression (with residuals)	Testing exogeneity assumption
Exogeneous ToC factors	Perceived vulnerability	−0.33 *	−0.50 ***	−0.37 *	−0.49 ***
	Perceived severity	0.37 *	0.60 ***	0.39 *	0.61 ***
	Perceived ease of access	0.95 ***	Endogenous	Endogenous	Endogenous
	Perceived Cost-Effectiveness	0.62 ***	0.91 ***	0.63 **	0.91 ***
	Descriptive Norms	0.84 ***	Endogenous	Endogenous	Endogenous
Predicted Endogenous ToC factors	ˆPerceived ease of access	–	2.39 ***	3.72 ***	1.87 *
	ˆDescriptive Norms	–	1.39 **	1.68 **	1.76 **
Instrument variables	Individualism-Collectivism	–	–	–	−0.54
	Work-Luck	–	–	–	0.16
	Generalized Morality	–	–	–	n.a
	Control	–	–	–	n.a
	Pseudo R^2	0.66	0.63	0.68	0.64

*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$; n.a. variable is excluded from the analysis to avoid redundancy. ˆPerceived ease of access is predicted by Work-Luck and Control; ˆDescriptive Norms is predicted by generalized morality and individualism-collectivism.

second-stage regression revealed much higher coefficients of 2.39 for perceived ease of access (a 152% increase) and 1.39 for norms (a 66% increase). The robustness checks confirmed that the coefficients for perceived ease of access and norms remained stable across specifications, and the main findings were not driven by outliers or specific covariate choices (see Table S4 in supplemental information). Detailed wording, response scales, and sources for all psychological and cultural variables included in the analysis are presented in Tables 5 and 6.

DISCUSSION

Psychological factors play a critical role in the adoption of a community-based water purification technology, but these factors are often endogenous, leading to biased estimations of their effect. In real-world scenarios, such bias could result in ineffective policy recommendations or misdirected interventions. For example, if the estimated effect of a psychological factor, such as perceived risk, is overstated, efforts may focus excessively on awareness campaigns while neglecting structural barriers such as accessibility or cost. Conversely, underestimating these effects could lead to missed opportunities for behavior-changing interventions. Specifically, in our study, we found that the endogeneity of perceived ease of access and descriptive norms led to underestimated effects by 175% and 76%, respectively. This highlights a significant issue with traditional estimation methods, which fail to account for endogeneity. As a result, they provide biased conclusions regarding the drivers of adoption behavior.[19]

Our results show that all significant psychological predictors, excluding perceived vulnerability, were positively associated with the adoption of water purification technology. The endogeneity of psychological factors, most notably perceived benefits and descriptive norms, highlights the importance of accounting for the bidirectional relationship between behavior and psychological determinants. The feedback effect implies that these psychological factors and water-related behaviors are mutually reinforcing, a dynamic that can result in what is termed a "reinforcing loop." This concept is supported by prior studies,[19] which highlight the interaction between behavior and psychological determinants in influencing health-related practices.

In the context of community-based water purification technologies, this reinforcement suggests that as more individuals adopt the technology, the social norms and perceived benefits surrounding its use become increasingly positive, further encouraging adoption within the community. For instance, when community members see that water purification systems are being adopted more widely, the perceived norm becomes stronger that people should adopt the technology, and they are more likely to comply. In the same way, people who adopt the system and use it on a regular basis are expected to exhibit a positive attitude toward its perceived benefits, thus driving their peers to adopt it as well. For example, in the community of Nagapady - Chottanikkara Ward 8, where around 40 households use it regularly, the system's success motivated neighboring Ward 9 to request a Jivamritam system in their area as well. Given the endogenous nature of these psychological factors, interventions designed to increase adoption must account for this mutual reinforcement to be effective. If such interactions are not taken into consideration, it means that key factors, such as perceived ease of access and descriptive norms, may be underestimated in their impact, limiting the effectiveness of such interventions. Future research could use system dynamic models that capture bi-directional feedback between psychological factors and behavior to further explore this dynamic. Such a model would enable us to track the changes in community attitudes and norms over time and provide estimates of reverse causality strength.

Table 5. Theory of Change (ToC) psychological factors

Determinant Group	Psychological Factor	Question Wording	Source
Perceived Risk	Perceived Vulnerability	How high is the risk that you will fall sick if you drink untreated water from other sources? (1 = no risk at all to 5 = very high risk)	Mosler[12]
	Perceived Severity	Last time you had diarrhea/water borne disease, how severe was the impact on your daily life? (1 = not severe at all to 5 = very severe)	Mosler[12]
	Perceived Safety	How safe is the water provided by Jivamritam? (1 = very safe to 5 = not safe at all)	Nancarrow[33]
Perceived Benefits	Perceived Taste	How much do you like the taste of water from Jivamritam? (1 = do not like at all to 5 = like very much)	Lilje and Mosler[34]
	Perceived Accessibility	How effortful is it to access Jivamritam from your house? (1 = very difficult to 5 = very easy)	Lilje and Mosler[34]
	Perceived Time Savings	How much time do you spend using Jivamritam? (1 = quite a lot of time to 5 = hardly any time)	Lilje and Mosler[34]
	Perceived Cost Efficiency	How cost effective is Jivamritam compared to other sources? (1 = not cost effective at all to 5 = very cost effective)	Lilje and Mosler[34]
Trust	Trust in the Implementing Agency	Do you trust the implementing agency, Amrita? (1 = no trust at all to 5 = very high trust)	Ross[35]
	Trust in Water Committee	How much trust do you have in the water committee with respect to governing and maintaining Jivamritam? (1 = no trust at all to 5 = very high trust)	Ross[35]
Social Norms	Descriptive Norms	What percentage of people in your community use Jivamritam? (1 = 0-20% to 5 = 80–100%)	Mosler[12]
	Injunctive Norms	People who are important to you, how much do they approve of using Jivamritam? (1 = very much oppose to 5 = very much approve)	Mosler[12]
Psychological Ownership	Individual Perspective	How much do you feel that you are one of the owners of Jivamritam? (1 = not at all to 5 = very much)	Contzen and Marks[17]
	Household Perspective	How much do you feel that your household is one of the owners of Jivamritam? (1 = not at all to 5 = very much)	Contzen and Marks[17]
	Community Perspective	How much do you feel that your community is one of the owners of Jivamritam? (1 = not at all to 5 = very much)	Contzen and Marks[17]
Perceived Ability	Self-Efficacy	How certain are you that you will always be able to use water from Jivamritam? (1 = not certain at all to 5 = very certain)	Mosler[12]

The findings of this study suggest that cultural factors can serve as potential instrumental variables for psychological determinants, such as perceived benefits, i.e., ease of access and descriptive norms, in the adoption of water purification technologies. Specific cultural traits, by shaping underlying psychological perceptions, can indirectly contribute to adoption behavior. The correct identification of these factors as IVs allows for a clearer understanding of the pathways through which psychological factors affect behavior, reducing biases such as endogeneity that can skew results. The cultural trait, work-luck, suggests that individuals who value hard work actively pursue solutions to overcome barriers to accessing technology, while

Table 6. Cultural factors

Cultural Factors	Question wording	Framework	Source
Generalized Trust	Do you trust your neighbors and community?	WVS	Tabellini[30]
Political Trust	How much trust you have in: Local Government - Panchayat, in general	WVS	Fitzgerald and Wolak[36]
Political Trust	How much trust you have in: Political parties in general	WVS	Saarinen[37]
Generalised Morality	Are tolerance and respect for other people, qualities that children should be encouraged to learn at home	WVS	Alesina[31]
Work-Luck	In the long run, hard work usually brings a better life	WVS	Tabellini[30]
Control	Some people feel they have completely free choice and control over their lives	WVS	Tabellini[30]
Individualism-Collectivism	Which do you believe in more: conforming to community values or being personally responsible for your own success and achievements	Hofstede's Cultural	Alesina[31]
Power Distance	How comfortable are you with deferring to greater authority, hierarchical or social	Hofstede's Cultural	Yang[38]
Family Ties	One of my main goals in life has been to make my parents proud	WVS	Li[39]

those who emphasize luck may passively wait for external circumstances to improve access. Beliefs about hard work versus luck influence social mobility and economic development.[30] Some view hard work as the path to success, while others attribute success to luck and connections. These views shape economic growth, with an emphasis on hard work historically driving industrialization and societal transformation. Research also shows that poor entrepreneurship and low literacy rates are linked to cultural traits such as a diminished sense of control over one's life.[30] Similarly, community members who feel in control of their own lives are likely to perceive fewer obstacles to using water purification systems. This empowerment fosters a positive association with the technology, making adoption more likely. Past studies have shown that control of one's life has a central role to play in a farmer's decision to adopt a particular technology[40] and that interventions and policies that seek to strengthen self-control are predicted to increase the welfare of people.[41] Empowered individuals may also contribute to the spread of positive norms surrounding the use of the system, which can further encourage community-wide adoption.

Generalized morality, another key cultural factor, directly impacts descriptive norms. Individuals who practice generalized morality prioritize the common good over self-interest.[30] Communities that emphasize tolerance and respect tend to promote behaviors that foster social cohesion. This behavior influences not only individual economic actions but also participation in group activities and public administration. Active engagement in local communities is crucial for organizing public goods and holding public officials accountable. In contrast, a lack of respect for the community and public affairs can lead to inadequate public good provision and encourage corruption, hindering economic development.[30] When communities operate in this way, the adoption of technologies such as water purification systems becomes normalized. Individuals in these communities are more likely to adopt the system because they perceive that "everyone is using it."

The individualism-collectivism dimension of culture also acts as an important determinant of descriptive norms.[42] In collectivist societies such as rural Indian communities,[43] where adhering to shared community values takes precedence over personal goals, descriptive norms exert greater influence on behavioral change. Individuals within collectivistic cultures are more influenced by group norms, shared responsibilities, and community obligations, which guide their behavior and decision-making. In the case of water purification technologies, once these systems are seen as accepted within the community, individuals are more compelled to adopt them to maintain social cohesion and fulfill their obligations to the group. The pressure to conform in collectivist cultures, hence, results in higher rates of adoption as the use of the system becomes not only an individual decision but one that has to do with one's commitment to a greater society. This aligns with findings from past studies, which observe that collectivism impacts attitude toward water purification technology via agreeableness.[44] In contrast, individualistic cultures might identify options that are convenient to the individual or self-interest as influencing adoption more than the collective there is.

This study not only highlights the indirect influence of cultural factors on human behavior but also establishes a robust theoretical framework for understanding how cultural traits impact technology adoption in rural communities. Interventions that take cultural factors into account can be more effective because they align with the community's values and beliefs, thereby increasing the likelihood of sustainable adoption. For a collectivistic community, for instance, interventions should focus on group-based campaigns, shared responsibility, and

collective benefits to foster community-wide adoption. For an individualistic community, highlight personal benefits and use tailored communication to appeal to individual decision-making. For a community practicing generalized morality, frame the intervention as a contribution to the common good, emphasizing how adoption benefits everyone by improving public health and community well-being. Provide skill-building workshops or training to reinforce the community's belief in hard work as a path to progress. While direct interventions on cultural factors may not be feasible, initiatives can succeed by leveraging cultural values and raising community awareness.

The study utilized data from 54 rural Indian communities to explore the endogeneity in the adoption of a community-based water purification technology through an instrumental variable approach. By employing cultural factors as instrumental variables, we effectively tackled the endogeneity present in the psychological determinants of perceived benefits and norms related to water technology adoption behavior. Our results demonstrated that cultural factors have a direct influence on perceived benefits and descriptive norms, highlighting the interconnectedness of cultural context and technology adoption.

The identification of endogeneity within the community-based water behavioral system reinforces the need to treat psychological factors as endogenous variables in analyses related to WASH. This recognition underscores the importance of employing nuanced analytical approaches that account for the dynamic interplay between psychological and cultural influences, ultimately leading to more accurate estimations of their effects. In addition, the findings of this study emphasize the critical need for interventions that are culturally informed and aligned with community values. By integrating cultural considerations into the design of adoption strategies, stakeholders can enhance the effectiveness and sustainability of technology adoption in rural communities. This study thus contributes valuable insights into future research and practical applications, advocating for a more holistic understanding of the factors that drive adoption behavior in community-based WASH-related initiatives.

Limitations of the study

The cross-sectional nature of our study restricts our ability to determine causality. While the study discusses a few cultural factors, it may not delve deeply into how specific cultural traits interact with psychological determinants or influence the adoption process in various contexts. Future studies should also consider factors inspired by the cultural heritage, traditions, and beliefs of the communities involved. The study primarily emphasizes psychological and cultural factors, potentially overlooking other important contextual factors (e.g., institutional, technological, or infrastructural) that could also impact technology adoption. Additionally, most constructs were assessed using single-item measures, which, while practical in large-scale field settings, may limit measurement reliability and construct depth. While a modified random-route sampling technique was used, potential sampling biases may persist due to voluntary participation and regional clustering. Also, we could not apply community-level clustering or survey weights due to the absence of structured community-level data and the use of a purposive, non-probabilistic sampling design.

RESOURCE AVAILABILITY

Lead contact

Further information and requests for resources should be directed to the lead contact: Maneesha V Ramesh, e-mail: maneesha@amrita.edu.

Materials availability

This study did not generate new unique reagents.

Data and code availability

- The dataset to perform the statistical analysis is deposited on Mendeley Data and is publicly available as of the date of publication (https://doi.org/10.17632/6fxjvd3844.1).
- The code used for statistical analysis is provided in the supplemental information and is publicly available as of the date of publication.
- The original survey questions are included in the main article and are publicly available as of the date of publication.

ACKNOWLEDGMENTS

The authors express their immense gratitude to Sri. Mata Amritanandamayi Devi (Amma), Chancellor of Amrita Vishwa Vidyapeetham, who has inspired them in performing selfless service to society. This project has been funded by the E4LIFE International Ph.D. Fellowship Program offered by Amrita Vishwa Vidyapeetham. We extend our gratitude to the Amrita Live-in-Labs academic program for providing all the support. This research is part of the Joint Center of Excellence in Water Sustainability, a collaborative initiative between Amrita Vishwa Vidyapeetham and Delft University of Technology.

AUTHOR CONTRIBUTIONS

Conceived and designed the research, M.R., S.P., and M.V.; conducted the research, M.R.; analyzed the results, M.R. and S.P.; writing—original draft, M.R.; and writing – review and editing: M.R., S.P., and M.V.

DECLARATION OF INTERESTS

S.P. is a member of the iScience Advisory Board.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
- EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAILS
  - Participants and data collection procedure
- METHOD DETAILS
  - Questionnaire and measures
  - Psychological (ToC) factors and contextual factors
  - Instrument variable (IV): Cultural factors
- QUANTIFICATION AND STATISTICAL ANALYSIS

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.isci.2025.113857.

Received: May 10, 2025
Revised: June 9, 2025
Accepted: August 27, 2025
Published: October 25, 2025

REFERENCES

1. Eman, K., and Meško, G. (2021). Water Crimes and Governance: The Slovenian Perspective. Int. Criminol. *1*, 208–219. https://doi.org/10.1007/s43576-021-00031-0.
2. UNICEF (2017). Thirsting for a Future: Water and Children in a Changing Climate (UNICEF). www.unicef.org/wash/waterandclimate.
3. United Nations Children's Fund and World Health Organization (2024). Progress on Household Drinking Water, Sanitation and Hygiene 2000–2022: Special Focus on Gender (World Health Organization). https://www.who.int/publications/m/item/progress-on-household-drinking-water–sanitation-and-hygiene-2000-2022—special-focus-on-gender.
4. World Health Organization (WHO) and United Nations Children's Fund (UNICEF) (2021). Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years into the SDGs (WHO and UNICEF). https://www.unicef.org/reports/progress-on-drinking-water-sanitation-and-hygiene-2021.
5. Ajith, V., Fishman, R., Yosef, E., Edris, S., Ramesh, R., Alookaran Suresh, R., Pras, A., Rahim, V., Rajendran, S., Yanko, M., et al. (2023). An integrated methodology for assessment of drinking-water quality in low-income settings. Environ. Dev. *46*, 100862. https://doi.org/10.1016/j.envdev.2023.100862.
6. Kanyagui, M.K., and Viswanathan, P.K. (2022). Water and sanitation services in India and Ghana: an assessment of implications for rural health and related SDGs. Water Policy *24*, 1073–1094. https://doi.org/10.2166/wp.2022.079.
7. Ghosal, S., and Ruj, C. (2023). Societal Impact Analysis of Community-managed Potable Water Supply System in Rural India. J. Appl. Soc. Sci. *17*, 148–167. https://doi.org/10.1177/19367244221119140.
8. Liddle, E.S., Mager, S.M., and Nel, E.L. (2016). The importance of community-based informal water supply systems in the developing world and the need for formal sector support. Geogr. J. *182*, 85–96. https://doi.org/10.1111/geoj.12117.
9. deWilde, C.K., Milman, A., Flores, Y., Salmerón, J., and Ray, I. (2008). An integrated method for evaluating community-based safe water programmes and an application in rural Mexico. Health Policy Plan. *23*, 452–464. https://doi.org/10.1093/heapol/czn017.
10. Ambuehl, B., Tomberge, V.M.J., Kunwar, B.M., Schertenleib, A., Marks, S.J., and Inauen, J. (2021). The Role of Psychological Ownership in Safe Water Management: A Mixed-Methods Study in Nepal. Water *13*, 589. https://doi.org/10.3390/w13050589.
11. Contzen, N., Kollmann, J., and Mosler, H.J. (2023). The importance of user acceptance, support, and behaviour change for the implementation of decentralized water technologies. Nat. Water *1*, 138–150. https://doi.org/10.1038/s44221-022-00015-y.
12. Mosler, H.J. (2012). A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. Int. J. Environ. Health Res. *22*, 431–449. https://doi.org/10.1080/09603123.2011.650156.
13. Rainey, R.C., and Harding, A.K. (2005). Acceptability of solar disinfection of drinking water treatment in Kathmandu Valley, Nepal. Int. J. Environ. Health Res. *15*, 361–372. https://doi.org/10.1080/09603120500289168.
14. Dreibelbis, R., Winch, P.J., Leontsini, E., Hulland, K.R.S., Ram, P.K., Unicomb, L., and Luby, S.P. (2013). The Integrated Behavioural Model for Water, Sanitation, and Hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. BMC Public Health *13*, 1015. https://doi.org/10.1186/1471-2458-13-1015.
15. Anthonj, C., Setty, K.E., Ferrero, G., A Yaya, A.M., Mingoti Poague, K.I.H., Marsh, A.J., and Augustijn, E.W. (2022). Do health risk perceptions motivate water - and health-related behaviour? A systematic literature review. Sci. Total Environ. *819*, 152902. https://doi.org/10.1016/j.scitotenv.2021.152902.
16. Boone, C., Glick, P., and Sahn, D.E. (2011). Household Water Supply Choice and Time Allocated to Water Collection: Evidence from Madagascar. J. Dev. Stud. *47*, 1826–1850. https://doi.org/10.1080/00220388.2011.579394.
17. Contzen, N., and Marks, S.J. (2018). Increasing the regular use of safe water kiosk through collective psychological ownership: A mediation analysis. J. Environ. Psychol. *57*, 45–52. https://doi.org/10.1016/j.jenvp.2018.06.008.
18. Huber, A.C., Tobias, R., and Mosler, H.J. (2014). Evidence-Based Tailoring of Behavior-Change Campaigns: Increasing Fluoride-Free Water Consumption in Rural E thiopia with Persuasion. Appl. Psychol. Health Well. Being. *6*, 96–118. https://doi.org/10.1111/aphw.12018.
19. Daniel, D., Pande, S., and Rietveld, L. (2022). Endogeneity in water use behaviour across case studies of household water treatment adoption in developing countries. World Dev. Perspect. *25*, 100385. https://doi.org/10.1016/j.wdp.2021.100385.
20. Abdallah, W., Goergen, M., and O'Sullivan, N. (2015). Endogeneity: How Failure to Correct for it can Cause Wrong Inferences and Some Remedies. Br. J. Manag. *26*, 791–804. https://doi.org/10.1111/1467-8551.12113.
21. Trinies, V., Freeman, M.C., Hennink, M., and Clasen, T. (2011). The role of social networks on the uptake of household water filters by women in self-help groups in rural India. J. Water, Sanit. Hyg. Dev. *1*, 224–232.
22. Cialdini, R.B., Kallgren, C.A., and Reno, R.R. (1991). A Focus Theory of Normative Conduct: A Theoretical Refinement and Reevaluation of the Role of Norms in Human Behavior. Adv. Exp. Soc. Psychol. *24*, 201–234. https://doi.org/10.1016/S0065-2601(08)60330-5.
23. Matsumoto, D. (2001). The Handbook of Culture and Psychology (Oxford university press).
24. Vásquez, W.F., Mozumder, P., and Franceschi, D. (2015). Water Quality, Household Perceptions and Averting Behavior: Evidence from Nicaragua. Water Econ Policy *01*, 1550011. https://doi.org/10.1142/S2382624X15500113.
25. Jan, J., Alshare, K.A., and Lane, P.L. (2024). Hofstede's cultural dimensions in technology acceptance models: a meta-analysis. Univers. Access Inf. Soc. *23*, 717–741. https://doi.org/10.1007/s10209-022-00930-7.
26. Merzlyakova, I., and Kiseleva, N. (2020). Modern Research on the Impact of Culture on Human Psychology. DEStech Transactions on Social Science, Education and Human Science, 330–334. https://doi.org/10.12783/dtssehs/ecemi2020/34704.
27. Matsumoto, D. (2007). Culture, context, and behavior. J. Pers. *75*, 1285–1319. https://doi.org/10.1111/j.1467-6494.2007.00476.x.
28. Minchekar, V.S., and Mangore, N.D.. (2022). Effect of psychological and cultural factors on consumer behaviour. Curr. Res. Psychol. Behav. Sci. *3*, 1039.
29. Slowikowski, S., and Jarratt, D.G. (1996). The Impact of Culture on the Adoption of High Technology Products. Asia Pac. J. Mark. Logist. *8*, 14–31. https://doi.org/10.1108/eb010276.
30. Tabellini, G. (2010). Culture and institutions: Economic development in the regions of Europe. SSRN Electronic Journal. http://SSRN.com/abstract=754086.
31. Alesina, A.F., and Giuliano, P. (2013). Culture and Institutions. Social Science Research Network. https://papers.ssrn.com/abstract=2370206.
32. Ajith, V., Mohan, R., Mohan, R., and Vinodini Ramesh, M. (2022). Empowering communities in addressing drinking water challenges using a systematic, participatory and adaptive approach and sustainable PPP model. Technol. Forecast. Soc. Change *185*, 121970. https://doi.org/10.1016/j.techfore.2022.121970.
33. Nancarrow, B.E., Porter, N.B., and Leviston, Z. (2010). Predicting community acceptability of alternative urban water supply systems: A decision making model. Urban Water J. *7*, 197–210. https://doi.org/10.1080/1573062X.2010.484500.
34. Lilje, J., and Mosler, H.J. (2018). Effects of a behavior change campaign on household drinking water disinfection in the Lake Chad basin using the

RANAS approach. Sci. Total Environ. *619–620*, 1599–1607. https://doi.org/10.1016/j.scitotenv.2017.10.142.

35. Ross, V.L., Fielding, K.S., and Louis, W.R. (2014). Social trust, risk perceptions and public acceptance of recycled water: testing a social-psychological model. J. Environ. Manage. *137*, 61–68. https://doi.org/10.1016/j.jenvman.2014.01.039.
36. Fitzgerald, J., and Wolak, J. (2016). The roots of trust in local government in western Europe. Int. Polit. Sci. Rev. *37*, 130–146. https://doi.org/10.1177/0192512114545119.
37. Saarinen, A., Koivula, A., and Keipi, T. (2020). Political trust, political party preference and trust in knowledge-based institutions. Int. J. Sociol. Soc. Policy *40*, 154–168. https://doi.org/10.1108/IJSSP-06-2019-0113.
38. Yang, J.S. (2019). Differential moderating effects of collectivistic and power distance orientations on the effectiveness of work motivators. Manag. Decis. *58*, 644–665. https://doi.org/10.1108/MD-10-2018-1119.
39. Li, L. (2010). Cultural Fit and Life Satisfaction: Endorsement of Cultural Values Predicts Life Satisfaction Only in Collectivistic Societies. https://www.academia.edu/25214393/Cultural_Fit_and_Life_Satisfaction_Endorsement_of_Cultural_Values_Predicts_Life_Satisfaction_Only_in_Collectivistic_Societies.
40. Bukchin, S., and Kerret, D. (2020). The role of self-control, hope and information in technology adoption by smallholder farmers – A moderation model. J. Rural Stud. *74*, 160–168. https://doi.org/10.1016/j.jrurstud.2020.01.009.
41. Duckworth, A.L. (2011). The significance of self-control. Proc. Natl. Acad. Sci. USA *108*, 2639–2640. https://doi.org/10.1073/pnas.1019725108.
42. Fischer, R., Ferreira, M.C., Assmar, E., Redford, P., Harb, C., Glazer, S., Cheng, B.S., Jiang, D.Y., Wong, C.C., Kumar, N., et al. (2009). Individualism-collectivism as Descriptive Norms: Development of a Subjective Norm Approach to Culture Measurement. J. Cross Cult. Psychol. *40*, 187–213. https://doi.org/10.1177/0022022109332738.
43. Varma, R. (2021). Dissecting culture at work: Conversation with Indian immigrant scientists & engineers in the US industrial sector. Technol. Soc. *66*, 101654. https://doi.org/10.1016/j.techsoc.2021.101654.
44. Abraham, J., Salsabilla, I., Warnars, H.L.H.S., Manurung, R.H., and Ruman, Y.S. (2021). Sustainability psychology of disruption: Attitude towards water purification technology can be predicted by cultural value orientation and personality traits. Sustainability *13*, 12638. https://doi.org/10.3390/su132212638.
45. Dheer, R.J.S., Lenartowicz, T., and Peterson, M.F. (2015). Mapping India's regional subcultures: Implications for international management. J. Int. Bus. Stud. *46*, 443–467. https://doi.org/10.1057/jibs.2014.70.
46. Hoffmeyer-Zlotnik, J.H. (2003). New sampling designs and the quality of data. Developments in Applied Statistics, 19, 205–217Data. https://www.researchgate.net/publication/254830834_New_Sampling_Designs_and_the_Quality_of_Data.
47. Aiswarya, A., Guntha, R., Ajith, V., Reshma, A.S., Suresh, S., Amrita, K., and Charan, P.S.V.V. (2023). Community empowerment through geospatial data collection: Presenting the Empower App: A secure, scalable and configurable mobile platform. In 2023 IEEE 11th Region 10 Humanitarian Technology Conference (R10-HTC) (IEEE. In: ResearchGate), pp. 1100–1105. https://doi.org/10.1109/R10-HTC57504.2023.10461924.
48. Mosler, H.J., and Contzen, N. (2016). Systematic Behavior Change in Water, Sanitation and Hygiene. A Practical Guide Using the RANAS Approach. Version 1.1 (Swiss Agency for Development and Cooperation SDC).
49. Daniel, D., Sirait, M., and Pande, S. (2020). A hierarchical Bayesian Belief Network model of household water treatment behaviour in a suburban area: A case study of Palu—Indonesia. PLoS One *15*, e0241904, Zia A. https://doi.org/10.1371/journal.pone.0241904.
50. Huber, A.C., and Mosler, H.J. (2013). Determining behavioral factors for interventions to increase safe water consumption: a cross-sectional field study in rural Ethiopia. Int. J. Environ. Health Res. *23*, 96–107. https://doi.org/10.1080/09603123.2012.699032.
51. Démolis, R., Botão, C., Heyerdahl, L.W., Gessner, B.D., Cavailler, P., Sinai, C., Magaço, A., Le Gargasson, J.B., Mengel, M., and Guillermet, E. (2018). A rapid qualitative assessment of oral cholera vaccine anticipated acceptability in a context of resistance towards cholera intervention in Nampula, Mozambique. Vaccine *36*, 6497–6505. https://doi.org/10.1016/j.vaccine.2017.10.087.
52. Lilje, J., Kessely, H., and Mosler, H.J. (2015). Factors Determining Water Treatment Behavior for the Prevention of Cholera in Chad. Am. J. Trop. Med. Hyg. *93*, 57–65. https://doi.org/10.4269/ajtmh.14-0613.
53. Altherr, A.M., Mosler, H.J., Tobias, R., and Butera, F. (2008). Attitudinal and Relational Factors Predicting the Use of Solar Water Disinfection: A Field Study in Nicaragua. Health Educ. Behav. *35*, 207–220. https://doi.org/10.1177/1090198106288251.
54. Daniel, D., Diener, A., Pande, S., Jansen, S., Marks, S., Meierhofer, R., Bhatta, M., and Rietveld, L. (2019). Understanding the effect of socio-economic characteristics and psychosocial factors on household water treatment practices in rural Nepal using Bayesian Belief Networks. Int. J. Hyg Environ. Health *222*, 847–855. https://doi.org/10.1016/j.ijheh.2019.04.005.
55. Heri, S., and Mosler, H.J. (2008). Factors Affecting the Diffusion of Solar Water Disinfection: A Field Study in Bolivia. Health Educ. Behav. *35*, 541–560. https://doi.org/10.1177/1090198108321248.
56. Huber, A.C., Bhend, S., and Mosler, H.J. (2012). Determinants of exclusive consumption of fluoride-free water: a cross-sectional household study in rural Ethiopia. J. Public Health *20*, 269–278. https://doi.org/10.1007/s10389-011-0445-z.
57. Murray, A.L., Napotnik, J.A., Rayner, J.S., Mendoza, A., Mitro, B., Norville, J., Faith, S.H., Eleveld, A., Jellison, K.L., and Lantagne, D.S. (2020). Evaluation of consistent use, barriers to use, and microbiological effectiveness of three prototype household water treatment technologies in Haiti, Kenya, and Nicaragua. Sci. Total Environ. *718*, 134685. https://doi.org/10.1016/j.scitotenv.2019.134685.
58. Roma, E., Bond, T., and Jeffrey, P. (2014). Factors involved in sustained use of point-of-use water disinfection methods: a field study from Flores Island, Indonesia. J. Water Health *12*, 573–583. https://doi.org/10.2166/wh.2014.109.
59. Opryszko, M.C., Majeed, S.W., Hansen, P.M., Myers, J.A., Baba, D., Thompson, R.E., and Burnham, G. (2010). Water and hygiene interventions to reduce diarrhoea in rural Afghanistan: a randomized controlled study. J. Water Health *8*, 687–702. https://doi.org/10.2166/wh.2010.121.
60. Freeman, M.C., Trinies, V., Boisson, S., Mak, G., and Clasen, T. (2012). Promoting Household Water Treatment through Women's Self Help Groups in Rural India: Assessing Impact on Drinking Water Quality and Equity. PLoS One *7*, e44068, Ibekwe AM. https://doi.org/10.1371/journal.pone.0044068.
61. Fotue, T.A.L., Sikod, F., and Abba, I. (2012). Household Choice of Purifying Drinking Water in Cameroon. Environ. Manag. Sustain. Dev. *1*, p101–p115. https://doi.org/10.5296/emsd.v1i2.1642.
62. Nauges, C., and Van Den Berg, C. (2009). Perception of health risk and averting behavior: An analysis of household water consumption in Southwest Sri Lanka. https://www.tse-fr.eu/publications/perception-health-risk-and-averting-behavior-analysis-household-water-consumption-southwest-sri.
63. Boo, Y.Y., Bora, A.K., Chhabra, S., Choudhury, S.S., Deka, G., Kakoty, S., Kumar, P., Mahanta, P., Minz, B., Rani, A., et al. (2024). Maternal and fetal factors associated with stillbirth in singleton pregnancies in 13 hospitals across six states in India: A prospective cohort study. Int. J. Gynaecol. Obstet. *165*, 462–473. https://doi.org/10.1002/ijgo.15367.
64. Asian Development Bank (2023). Gender Equality and Water Security: A Conceptual Framework (Asian Development Bank). https://www.adb.org/publications/gender-equality-water-security-conceptual-framework.
65. Rosa, G., Kelly, P., and Clasen, T. (2016). Consistency of Use and Effectiveness of Household Water Treatment Practices among Urban and Rural Populations Claiming to Treat Their Drinking Water at Home: A Case Study

in Zambia. Am. J. Trop. Med. Hyg. *94*, 445–455. https://doi.org/10.4269/ajtmh.15-0563.

66. Foster, E.M., and McLanahan, S. (1996). An illustration of the use of instrumental variables: Do neighborhood conditions affect a young person's chance of finishing high school? Psychol. Methods *1*, 249–260. https://doi.org/10.1037/1082-989X.1.3.249.

67. Guiso, L., Sapienza, P., and Zingales, L. (2011). Civic capital as the missing link. Handbook of social economics *1*, 417–480. https://www.taylorfrancis.com/chapters/edit/10.4324/9781849776592-1/trust-risk-perception-tcc-model-cooperation-1-timothy-earle-michael-siegrist-heinz-gutscher.

68. Boyd, R., and Richerson, P.J. (2005). The Origin and Evolution of Cultures (Oxford University Press).

69. Hofstede, G. (1980). Culture and organizations. Int. Stud. Manag. Organ. *10*, 15–41. https://www.tandfonline.com/doi/abs/10.1080/00208825.1980.11656300.

70. Huang, F., Teo, T., Sánchez-Prieto, J.C., García-Peñalvo, F.J., and Olmos-Migueláñez, S. (2019). Cultural values and technology adoption: A model comparison with university teachers from China and Spain. Comput. Educ. *133*, 69–81.

71. Mallick, A. (2013). Multiculturalism, minority rights and democracy in India. IOSR Journal of Humanities and Social Sciences *16*, 72–82. https://www.researchgate.net/publication/315645988_Multiculturalism_Minority_Rights_and_Democracy_in_India.

72. Hofstede, G., and Hofstede, G. (2001). Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations (Thousand Oaks, CA: Sage Publications. *Cult Consequences Comp Values Behav Inst Organ Nations*). https://doi.org/10.1016/S0005-7967(02)00184-5.

73. Inglehart, R., Basanez, M., Diez-Medrano, J., Halman, L., and Luijkx, R. (2000). World Values Surveys and European Values Surveys, 1981-1984, 1990-1993, and 1995-1997 (Ann Arbor, MI: Institute for Social Research, ICPSR version. ResearchGate). https://www.researchgate.net/publication/236174696_World_Values_Surveys_and_European_Values_Surveys_1981-1984_1990-1993_and_1995-1997.

74. Knack, S., and Keefer, P. (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation. Q. J. Econ. *112*, 1251–1288. https://doi.org/10.1162/003355300555475.

75. Butler, J.V., Giuliano, P., Guiso, L., Butler, J.V., Giuliano, P., and Guiso, L. (2016). The right amount of trust. J. Eur. Econ. Assoc. *14*, 1155–1180.

76. van der Meer, T.W.G. (2017). Political Trust and the "Crisis of Democracy". In Oxford Research Encyclopedia of Politics, W.R. Thompson, ed. (Oxford University Press). https://doi.org/10.1093/acrefore/9780190228637.013.77.

77. Earle, T.C., Siegrist, M., and Gutscher, H.. Trust, Risk Perception and the TCC Model of Cooperation 1. https://www.researchgate.net/publication/254911577_Trust_Risk_Perception_and_the_TCC_Model_of_Cooperation1.

78. Zumeri, S., and Bandura, A. (1997). Self-efficacy: The exercise of control (Vol. 11). Freeman. https://www.academia.edu/28274869/Albert_Bandura_Self_Efficacy_The_Exercise_of_Control_W_H_Freeman_and_Co_1997_pdf.

79. Singelis, T.M., and Brown, W.J. (1995). Culture, self, and collectivist communication: Linking culture to individual behavior. Hum. Commun. Res. *21*, 354–389. https://www.researchgate.net/publication/11106109_Culture_Self_and_Collectivist_Communication_Linking_Culture_to_Individual_Behavior.

80. Oyserman, D., Coon, H.M., Kemmelmeier, M., Oyserman, D., Coon, H.M., and Kemmelmeier, M. (2002). Rethinking individualism and collectivism: Evaluation of theoretical assumptions and meta-analyses. Psychol. Bull. *128*, 3–72. https://doi.org/10.1037/0033-2909.128.1.3.

81. Huang, L., Lu, M.T., and Wong, B.K. (2003). The impact of power distance on email acceptance : evidence from the PRC. J. Comput. Inf. Syst. *44*, 93–101. https://doi.org/10.1080/08874417.2003.11647556.

82. Homocianu, D. (2023). Exploring the Predictors of Co-Nationals' Preference over Immigrants in Accessing Jobs—Evidence from World Values Survey. Mathematics *11*, 786. https://doi.org/10.3390/math11030786.

83. Kraemer, S.M., and Mosler, H.J. (2010). Persuasion factors influencing the decision to use sustainable household water treatment. Int. J. Environ. Health Res. *20*, 61–79. https://doi.org/10.1080/09603120903398301.

84. Houweling, T.A., Kunst, A.E., and Mackenbach, J.P. (2003). Measuring health inequality among children in developing countries: does the choice of the indicator of economic status matter? Int. J. Equity Health *2*, 8. https://doi.org/10.1186/1475-9276-2-8.

85. Wooldridge, J.M. (2010). Econometric Analysis of Cross Section and Panel Data (MIT Press). https://ipcid.org/evaluation/apoio/Wooldridge%20-%20Cross-section%20and%20Panel%20Data.pdf.

86. Roberts, M.R., and Whited, T.M. (2013). Endogeneity in Empirical Corporate Finance. In Handbook of the Economics of Finance, *Vol 2A*, G.M. Constantinides, M. Harris, and R.M. Stulz, eds. (Elsevier), pp. 493–572. https://doi.org/10.1016/B978-0-44-453594-8.00007-0.

87. Bascle, G. (2008). Controlling for endogeneity with instrumental variables in strategic management research. Strateg. Organ. *6*, 285–327. https://doi.org/10.1177/1476127008094339.

88. Bollmann, G., Rouzinov, S., Berchtold, A., and Rossier, J. (2019). Illustrating Instrumental Variable Regressions Using the Career Adaptability – Job Satisfaction Relationship. Front. Psychol. *10*, 1481. https://doi.org/10.3389/fpsyg.2019.01481.

89. Troy, T.J., Konar, M., Srinivasan, V., and Thompson, S. (2015). Moving sociohydrology forward: a synthesis across studies. Hydrol. Earth Syst. Sci. *19*, 3667–3679. https://doi.org/10.5194/hess-19-3667-2015.

90. French, M.T., and Popovici, I. (2011). That instrument is lousy! In search of agreement when using instrumental variables estimation in substance use research. Health Econ. *20*, 127–146. https://doi.org/10.1002/hec.1572.

91. Terza, J.V., Basu, A., and Rathouz, P.J. (2008). Two-stage residual inclusion estimation: Addressing endogeneity in health econometric modeling. J. Health Econ. *27*, 531–543. https://doi.org/10.1016/j.jhealeco.2007.09.009.

STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Survey data	This study	Mendeley data: https://doi.org/10.17632/6fxjvd3844.1
Software and algorithms		
R Project for statistical computing	http://www.r-project.org/	RRID:SCR_001905
R package: dplyr	https://cran.r-project.org/package=dplyr	RRID:SCR_016708
R package: readr	https://cran.r-project.org/package=readr	RRID:SCR_018546
R package: stats	http://www.r-project.org/	RRID:SCR_001905
R package: pscl	https://cran.r-project.org/package=pscl	RRID:SCR_018666
Empower Survey Platform	https://play.google.com/store/apps/details?id=edu.amrita.empower&hl=en-US&pli=1/#/	N/A

EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAILS

Participants and data collection procedure

Building on the Theory of Change (ToC) framework by[11] and drawing from qualitative insights gathered during field visits to rural communities where Jivamritam has been implemented, we identified the most relevant psychological determinants and contextual factors through a quantitative analysis of data collected from 54 communities. Logistic regression was primarily used to analyse the associations between determinants, contextual factors and technology adoption patterns. We carried out a cross-sectional study to examine the psychological and contextual factors explaining the adoption of Jivamritam in rural communities across six Indian states: Kerala, Karnataka, Andhra Pradesh, Odisha, Uttar Pradesh and Himachal Pradesh, where the technology had already been implemented. Out of 300 communities where Jivamritam was installed, 75, heavily impacted by water contamination were initially selected. Of these, 64 expressed interests in participating, and a final selection of 54 communities, representing a diverse range of cultural, geographical and environmental characteristics (for a snapshot, see S-5), as identified by,[45] were chosen for data collection.

Data collection took place over six weeks during July and August 2023, using structured in-person interviews with household members in participating communities. A modified random route sampling technique[46] was applied to ensure unbiased household selection. Each community was split into five zones based on identifiable landmarks, and interviewers were randomly allocated to these zones. In each zone, a house was selected at random as the starting point, and from there, interviewers approached every second household along a predetermined path to conduct interviews. The response rate was notably high, with only 89 households (8%) opting out of participation. The interviews were conducted with the individuals responsible for water collection within the household. Participation was entirely voluntary, and informed consent was obtained either in writing or verbally, given the high illiteracy rates in some areas. Verbal consent was documented by the interviewer through a signed statement. The study adhered to ethical guidelines, with the protocol being reviewed and approved by the University's ethical review board. Additionally, written permission to conduct the survey was granted by the president of the local governing body in each community. Each interview lasted approximately 45 minutes and was conducted in one of five local languages: Malayalam, Hindi, Kannada, Telugu, or Odia, depending on the respondent's native language. A team of four interviewers, consisting of the first author, university staff, a Jivamritam implementation team member and the local village coordinator, carried out the interviews. All interviewers underwent specialized training in interview techniques and were closely monitored by the first author and a local field research facilitator throughout the data collection process. The questionnaire was administered using the Empower mobile application,[47] which streamlined the interview process.

A total of 906 individuals participated in this study, which encompassed 54 different rural Indian communities. Among the respondents, 70% were female, with ages ranging from 19 to 77 years (M = 48.66, SD = 8.32). With respect to education levels, 4% had no formal schooling, 28% completed primary education, 64% attained secondary education, and 4% held a university degree or another advanced qualification. Furthermore, 91% of the households involved were classified as living below the poverty line.

METHOD DETAILS

Questionnaire and measures

The study utilized a structured survey for conducting interviews, which focused on demographic information, sources of drinking water and psychological factors explaining the adoption of Jivamritam. Questions were formulated in English and collaboratively

reviewed in a brainstorming session with members from the Jivamritam implementation team and technology specialists. The resulting questionnaire was then translated into five local languages used in the participating communities, followed by back-translation into English to verify the accuracy of the translations. A pretest was conducted with 15 participants from communities where Jivamritam had been installed, leading to further revisions aimed at enhancing the clarity of certain questions. Following sections elaborate the specific measures utilized in this research.

Psychological (ToC) factors and contextual factors

The psychological factors determining the adoption of Jivamritam were evaluated using the RANAS approach.[12,48] The RANAS model, designed for the water, sanitation, and hygiene sector in developing countries, incorporates psychological factors from major behaviour change theories into five comprehensive factor groups: Risk, Attitudes, Norms, Abilities, and Self-Regulation. However, three specific aspects: perceived risks associated with using or not using the technology, trust and psychological ownership were included additionally. Detailed information about the wording and response scales for measuring these psychological determinants, along with their sources can be found in Table 5. Each ToC factor was represented by a single item, except for psychological ownership, which consisted of three items. Given the high internal consistency of these three items (Cronbach's alpha = 0.95), their responses were combined to create a composite score. All items utilized a 5-point Likert scale for responses.

The psychological factors are listed as follows. The adoption of water purification technologies is driven by individuals' awareness of health risks from consuming untreated water, particularly when they have greater knowledge of water-borne diseases and perceive a higher vulnerability and severity of contracting such diseases.[15,49–51] Perceived costs and benefits of using the water purification technology, including cost-effectiveness, ease of access and time-saving advantages are key psychological determinants contributing to its adoption, with greater perceived benefits linked to increased adoption.[16–18,34] Trust in the implementing agency and the local water committee, responsible for maintaining and overseeing the water purification technology can reduce perceived risks and promote adoption.[11]

Perceived descriptive norms suggest that community members may be more inclined to adopt and sustain the use of water purification technology if they believe that a significant number of other community members are also using it.[17,18,32,52,53] Perceived injunctive norms imply that individuals are more inclined to adopt the technology when they perceive that others expect them to follow suit, reinforcing the perceived social obligation to use the technology.[34] Psychological ownership of the water purification technology refers to members of the community taking personal responsibility for its upkeep and functioning, treating the system as if it were their own. This sense of ownership is likely to foster greater commitment to the adoption and sustained use of the technology.[10,17] Perceived ability, encompassing familiarity with the technology, access to necessary resources, confidence in consistent usage despite challenges and the ability to handle technical problems, is likely to contribute to higher rates of adoption and continued use of the technology.[17,54–57]

Contextual factors, also explain the adoption of community-based water purification technology. For instance, the distance of a household from the technology may impact the perceived effort required for its use, as closer proximity reduces the physical and time demands of water collection, making the system more accessible and convenient, leading to increased adoption.[16] Additionally, when more family members are involved in fetching water, the perceived effort decreases, further promoting the water purification technology's adoption.[16]

Socio-economic characteristics (SEC) of community members were incorporated as control variables. Two SEC variables, specifically wealth[58,59] and education level[60–62] were selected based on their established associations with household water treatment (HWT) adoption, from past research.[19] Wealth was assessed by the classification of households based on the ration card system issued by the government, distinguishing between those below and above the poverty line.[63] The education level was evaluated by identifying the highest completed level of education among respondents, with response categories including "None," "Primary," "Secondary," and "Graduate or Above." In addition, gender of the respondent and household size (number of family members living in the household) were included as demographic control variables, as both factors shape water decisions. Women and girls are primarily responsible for water collection in many low- and middle-income settings,[64] and larger households may face higher water demand and logistical complexity that can hinder consistent use of treated water.[65]

To evaluate the distance between households and Jivamritam, respondents were asked to indicate how far their homes were from the facility, choosing from the following categories: 1 = 0-50 meters; 2 = 50-100 meters; 3 = 100-150 meters; 4 = 150-200 meters and 5 = over 200 meters. Responses were then recoded into 2 groups: 1 for households located greater than 100 m away, and 0 for households located less than 100 m away. Additionally, we inquired, "How many family members help you fetch water?" with options scaled from "0" to "4." This question was intended to assess how many of the family members help in taking water from Jivamritam. Responses were recoded to give a score of 0 if no family members participated and a score of 1 if at least one family member participated.

Instrument variable (IV): Cultural factors

Criteria for IV stipulate that the instrumental variable must have a strong association with psychological factors while exerting only an indirect influence on behaviour.[19] This means that the relationship between the IV and behavior is mediated through the psychological constructs. Identifying an appropriate IV that satisfies these conditions presents a considerable challenge.[66]

In this study, we propose cultural factors as valid instruments. Culture refers to the traditional beliefs and values that ethnic, religious, and social groups transmit across generations,[67] functioning as decision-making heuristics for navigating complex environments through values, beliefs and norms[68] and representing the "accumulative programming of the human mind" that differentiates groups.[69] Defined more broadly, culture is a shared system of values, norms, and beliefs that guide individual and collective behaviour, is relatively stable over time and not easily influenced by short-term behavioural shifts.[30] This temporal stability makes cultural factors less susceptible to reverse causality and strengthens their validity as exogenous variables. Also, culture influences behaviour indirectly through its effect on psychological variables. Cultural values such as interpersonal trust or respect for authority shape cognitive and emotional responses, such as attitudes, perceived norms, risk perception and self-efficacy, that in turn influence technology-related decisions.[70] This aligns with the second IV requirement: that cultural variables affect adoption behaviour only through psychological constructs, satisfying the exclusion restriction.

Culture, in our study, is assessed through indicators of personal values and beliefs, such as trust and respect for others, as well as confidence in self-determination, providing a foundation for understanding cultural influences on behavior.[30] Hofstede's Cultural Dimensions and the World Values Survey are frameworks used to measure and analyse these abstract cultural factors. Although our study is confined to India, the country's immense cultural diversity across languages, religions, and community norms makes such cross-cultural indicators meaningful and relevant at a subnational level.[71]

Hofstede's model quantifies cultural differences based on six dimensions: i) Power Distance Index (PDI); ii) Individualism vs. Collectivism (IDV); iii) Uncertainty Avoidance Index (UAI); iv) Masculinity vs. Femininity (MAS); v) Long-Term vs. Short-Term Orientation (LTO); and vi) Indulgence vs. Restraint (IND).[72] This framework helps understand how cultural programming shapes behaviors and highlights the unique values and norms that define different groups. Power Distance is the degree to which a society accepts unequal power distribution. Uncertainty Avoidance measures the society's tolerance for uncertainty. Masculinity is the expression of traditional male values around performance and control. Long-Term Orientation, which stresses values associated with thrift and perseverance versus those of tradition and fulfilling social obligations. Indulgence versus Restraint (IND) differentiates societies based on the extent to which they permit the relatively free gratification of basic human desires associated with enjoying life or suppresses gratification through strict social norms; it is linked to consumer habits as well as social interactions. While there have been critiques of Hofstede's framework, it still remains one of the most frequently cited frameworks in a variety of disciplines such as international business, management and applied psychology.[31]

World Values Survey (WVS) provides a systematic study of people's values and norms that enables cross-cultural and longitudinal comparisons.[73] The survey identifies two key dimensions of cross-cultural variation: i) Traditional versus Secular-rational values ii) Survival versus Self-expression values. Religion, family ties and authority are highlighted in the traditional category; in contrast, secular-rational values reject these norms and accept issues such as divorce and abortion. Survival values emphasize financial and physical security and have a more ethnocentric outlook, while self-expression values prioritize environmental protection, tolerance, gender equality and participatory decision-making in social issues. The survey focuses on specific indicators, including measures of trust, respect for others and the perceived connection between individual effort and development. Together, these frameworks operationalize culture into specific, measurable indices, enabling a comprehensive study of its impact on individual and societal behaviors.

Table 6 shows the selected questions from Hofstede's Cultural Dimensions and the World Values Survey frameworks to measure and analyze these abstract cultural factors. The cultural trait most commonly studied is generalized trust, that is, the trust that individuals place on one another. Trust impacts various aspects of development, including economic growth,[74] individual performance[75] and financial market engagement.[67] The WVS also captures political trust, defined as trust in government bodies and political parties, which varies widely across the globe according to their data.[76] Political trust represents how much trust individuals have in these institutions, reflecting regional and national differences in political engagement. Previous studies suggest that greater trust in water management authorities is associated with reduced perceptions of risk related to using water purification technologies, more favourable views of water quality, and increased recognition of the benefits of the infrastructure.[11,77]

Generalized morality, as described by,[30] refers to the concept of extending cooperative behavior and moral obligations to all members of society, rather than limiting them to close family or kin. It contrasts with "limited morality," where cooperation and ethical behavior are primarily directed only towards immediate family members.[30] highlights that societies embracing generalized morality tend to experience better social trust, stronger institutions, and more robust economic development, as cooperation extends beyond familial ties and benefits the broader community. Consequently, one could infer that generalized morality, by fostering cooperation and trust within society beyond familial or close-knit groups, can indirectly promote the adoption of community-based water purification technologies. In societies where generalized morality prevails, individuals are more likely to trust and engage with community-based initiatives, including water management systems.

Another cultural factor frequently cited as a key contributor to economic development is the belief that individual effort will yield rewards, reflected in the "Work vs. Luck" question of WVS. Those who believe that hard work and personal effort lead to success, feel a greater inclination to initiate things than those who believe success is determined by luck and take passive approach.[31] In relation to the adoption of community-based water purification technologies, this mindset indicates that people who perceive the capacity to control results by their own efforts feel more confident about committing their involvement in adopting this kind of technology.

The cultural variable "Control" measures the perception of personal freedom and influence over one's life, based on responses to a survey question if the individuals feel they have control over their lives. People who believe they have a significant amount of control

over their lives are generally more proactive. They will most probably go for opportunities, take actions and pursue their objectives believing that the way they act can determine the outcomes to a large extent.[78] Here a strong feeling of control prompts positive engagement in the adoption cycle itself: willingness to assist with implementation, and/or engage in maintenance or stewardship of these technologies.

In collectivistic societies, people prioritize group interests and are more likely to internalize shared goals, making collective action easier.[38] Social behaviors in collectivist societies are primarily shaped by social norms, with individuals feeling bound by mutual obligations within their group.[79,80] In such cultures, prioritizing group goals over personal interests is the norm. Collectivists are willing to make personal sacrifices to maintain close, harmonious relationships and contribute to group success.[38] In contrast, individualistic societies emphasize personal achievements, individual rights and self-reliance, expecting people to prioritize themselves while choosing their affiliations independently. In collectivist societies, strong social norms emphasize group harmony and the collective well-being, making individuals more likely to adopt community-based water purification systems as a way to benefit the entire community.

Power distance (PD) refers to the degree to which members of a society or organization accept and anticipate an unequal distribution of power.[81] In high PD societies, hierarchical structures and centralized decision-making are the norm, with power concentrated at the top and lower-ranking individuals less likely to challenge authority.[69] This is quite the opposite of low PD societies that are likely to be more equal society and therefore ensure equal share of power. In high power distance societies such as Indian communities,[43] the hierarchical structure may help enable key decision-makers, such as community leaders or government officials, to influence and expedite the adoption of community-based water purification systems. The acceptance of authority by individuals encourages compliance and participation, making it easier to implement new technologies at the community level.

Another crucial cultural value is the significance of family ties in society.[82] indicates that individuals motivated by the desire to make their parents proud are more likely to align their decisions with the expectations of their families and communities. The correlation between this motivation and power distance or the acceptance of hierarchical relationships, further emphasizes how cultural values affect social dynamics. In societies where hierarchical relationships and family obligations are prioritized, this alignment fosters collective decision-making and increases participation in initiatives like community-based water purification systems, as individuals are likely to follow decisions endorsed by family or community leaders. All cultural instruments were respondent-reported via adapted WVS/Hofstede items.

QUANTIFICATION AND STATISTICAL ANALYSIS

The study employed a two-stage regression analysis to estimate the effect of psychological determinants on the adoption of Jivamritam, while addressing potential endogeneity, as outlined in Figure 4. Endogeneity may arise when psychological determinants such as perceived norms and ease of access are themselves influenced by prior exposure to the technology, leading to reverse causality and biased estimates. To isolate their causal effect, we instrumented these variables using cultural indicators that are theoretically exogenous and empirically validated. R version 4.2.3 was used for all analyses (R Core Team 2023). The R code used for model specification; imputation and IV diagnostics is provided in the supplemental information (Table S3).

Step 1: Unweighted Logistic Regression.

The response variable, Jivamritam adoption, was measured by asking, ‘‘Do you regularly use water from Jivamritam in your community?’’ with a binary response: 1 = Yes, 0 = No. An unweighted logistic regression model was first used to assess the influence of socio-economic (SEC), contextual, demographic and psychological variables on adoption.[19,83] To quantify overall socio-economic status, Principal Component Analysis (PCA) was applied to respondents’ wealth and education indicators.[84] As both variables were standardized and contributed equally to the first principal component, they had loadings of approximately 0.707 each.

To assess whether psychological variables were endogenous, we followed Wooldridge’s (2010)[85] Wald test procedure. In the first stage, each psychological factor was regressed on its corresponding IVs, and residuals were saved. These residuals were then included as regressors in the second-stage logistic regression. A statistically significant residual coefficient indicated endogeneity. Only those psychological variables identified as endogenous through this procedure were instrumented using IVs in the second stage.

Step 2: First-Stage Regression.

To address this endogeneity, we implemented a two-stage regression approach using cultural factors as instrumental variables (IVs). The two-stage regression method is a well-established technique in econometrics for addressing endogeneity issues[86] and allows researchers to obtain unbiased estimates of how psychological factors explain adoption behavior.[87] Yet it remains underutilized in psychological research and studies focusing on water systems and socio-hydrology.[88,89]

In the first stage, psychological factors suspected to be endogenous were predicted using theoretically grounded and empirically validated cultural instrumental variables (IVs), thereby reducing the correlation between the error term and the endogenous predictors. These IVs, such as Generalized Morality, Individualism-Collectivism, Work-Luck beliefs and Control orientation were chosen based on conceptual alignment with specific psychological factors. For instance, Generalized Morality and Individualism-Collectivism were hypothesized to influence perceived social norms, while Work-Luck and Control beliefs were linked to perceived access. Each IV–psychological factor pairing was conceptually grounded, and IVs were uniquely assigned to avoid multicollinearity

and overfitting. For instance, if Generalized Morality was used to predict perceived benefits, it was not reused for other constructs such as norms. To ensure validity, IVs were required to meet two key criteria:

1. Relevance: IVs must have a strong association with the psychological determinants. This was tested using Ordinary Least Squares (OLS) regressions. IVs were retained only if they showed R^2 values > 0.25 and F-statistics > 10, consistent with thresholds used to avoid weak instruments.[90]
2. Exogeneity: IVs must be exogenous, meaning they should not have a direct correlation with the adoption outcome after controlling for the endogenous psychological variables and other regressors in the model.[30] This involved regressing adoption outcomes on SEC, predicted psychological variables, other exogenous psychological factors and the original IVs. The IVs were considered valid if their coefficients were statistically non-significant in this model. This ensures that the IV influences Jivamritam adoption only through its effect on the endogenous explanatory variables.

The predicted values and residuals from these first-stage models were stored for the final stage of analysis. This process ensured that the resulting predicted psychological variables are purged of endogeneity, allowing unbiased estimation of their effects on Jivamritam adoption in the second-stage regression. In selecting IVs, we tested multiple combinations of cultural factors and retained only those that satisfied the following three conditions: (i) an R^2 value greater than 0.25, indicating strong predictive capability, (ii) the predicted endogenous psychological variable significantly predicted adoption in the second-stage logistic model, and (iii) the IV itself showed no significant direct effect on adoption.

This modelling approach assumes that psychological variables serve as the primary pathway through which cultural traits influence adoption behaviour. Any remaining correlation between IVs and Jivamritam adoption, despite the presence of endogenous variables, may arise from the psychological variables employed in the analysis not being exhaustive, suggesting the potential for additional unobserved endogenous variables. While residuals from first-stage regressions capture unexplained portions of the psychological variables, they address endogeneity only in the included predictors (the correlation between the endogenous variables and the error term). While this limitation suggests potential omitted pathways, the IV approach still offers a more robust alternative to direct estimation.

Step 3: Second stage Logistic regression.

We then performed a logistic regression using the predicted values of the endogenous psychological variables, along with remaining exogenous predictors. By using instrumented psychological factors free from reverse causality, this model provides more reliable estimates of their effect on Jivamritam adoption. Results were compared with those from the initial un-instrumented model to assess the impact of addressing endogeneity. We conducted robustness checks to assess potential overfitting and sensitivity to influential observations. These included re-estimating the models after excluding high-influence cases and under alternative model specifications. In addition, we note that our two-stage procedure aligns with the variance-preserving two-stage residual inclusion (2SRI) framework, which is a consistent estimator of second-stage effects in nonlinear models.[91]