Received: 27 April 2022 | Accepted: 24 February 2024

DOI: 10.1111/1467-8489.12563

The Australian Journal of Agricultural and Resource Economics

AARES AUSTRALASIAN AGRICULTURAL & RESOURCE ECONOMICS SOCIETY

ORIGINAL ARTICLE

Insights into preferences for irrigation pumps in West Bengal: An application of best-worst-scaling

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Funding information
Australian Centre for International Agricultural Research, Grant/Award Number: LWR/2018/104

Abstract

This paper presents an analysis of the heterogeneous preferences of farmers towards groundwater pump technologies. The research uses primary field data drawn from West Bengal, India, where the progressive feminisation of agriculture has been well-documented. We employ a paired comparison technique to explore how gender impacts the preferences towards different attributes of pumping technology. Our findings illustrate that preferences for irrigation pump attributes vary significantly between farmer groups, and policies that put technologies in the hands of some groups versus others could have significantly different impacts on how pumps are ultimately used.

KEYWORDS

agricultural development, India, irrigation technology, paired comparison, West Bengal

1 | INTRODUCTION

The state of West Bengal in India is the most populous jurisdiction in the Eastern Gangetic Plains (EGP). It provides a valuable backdrop for considering the role of groundwater pumping technologies and its links to reducing poverty. Although physically abundant, groundwater is economically scarce in the state, and it is this 'economic scarcity of groundwater' (Mukherji, 2007) that has been pointed to as one reason for agricultural stagnation in the region (Kishore, 2021, 2004; Mukherji, 2007). The relatively high cost of owning a pump set[1] for irrigation means farmers generally do not optimise groundwater use from a cropping perspective, resulting in low yields, increased vulnerability to heatwaves and droughts, and subsequently lower profits and poorer livelihoods (Kishore, 2021).

[1]In South Asia, many pumps used for groundwater extraction are portable and comprise an engine that uses fossil fuel (diesel) coupled with a lift pump. The expansion of the electricity grid has seen pumps converted to electric motors, but the term 'pump set' remains widely in place.

In India, water management and pumping are generally viewed as activities that men are in charge of, particularly in West Bengal. The exclusion of women from this domain occurs even though women contribute the majority of agricultural labour (Mukhopadhyay et al., 2023; Pattnaik & Lahiri-Dutt, 2020). This dynamic creates several complexities, especially where male out-migration increases the reliance on women's contribution to the agricultural sector. More specifically, questions arise around whether women share the same preferences for groundwater pumping technologies as men and, if there are differences, whether they have potential consequences on the choice, adoption and use of pumping technologies. If women are increasingly left to make decisions about agricultural production, but technologies remain geared towards men, then the likelihood of enhancing the welfare of the rural poor through raised agricultural productivity is diminished.

This research investigates the preferences for pumping technology by smallholder farmers and specifically considers differences in preferences from the perspective of gender. While understanding preferences and tailoring support around them does not guarantee the increased use of a technology, we contend that data on preferences offer valuable insights. In particular, this knowledge can guide policies that can improve the sustainability of groundwater use and promote more efficient use of pumping technologies.

The paper contributes to the literature on understanding the links between gender and the adoption of water-related technologies in a developing country context (see, e.g., Mu et al., 1990; Oca & Bateman, 2006; Scarpa et al., 2012). We consider the nuances between pump features and use these to assess willingness to adopt specific technologies from a gender perspective. The paper presents a unique paired comparison choice experiment to generate primary data on farmers' preferences for pumping technologies. Equipped with these data on preferences, we then discuss how some policy options might result in different adoption and use outcomes for smallholders.

The paper itself comprises six additional parts. In Section 2, we briefly provide the background that sets the context for the research. This section also summarises the role of pumping technologies and their interplay with groundwater markets. In Section 3, we outline the method used to determine preferences for pump set attributes of different groups of farmers in West Bengal—a paired comparison choice experiment. The results of this experiment are presented in Section 4 and are subsequently used to discuss policy implications in Section 5. The paper ends with concluding remarks.

2 | THE CONTEXTUAL SETTING

The out-migration of men from agriculture to access perceived better economic opportunities in other sectors or locations is well-documented in the literature (see, e.g., Mukhopadhyay et al., 2023). The resulting feminisation of agriculture has been observed across South Asia and Africa, but debate continues around the details of the rural transformation that ensues. On the one hand, feminisation can result in women simply doing more work as their share of the agricultural labour force increases. On the other hand, feminisation might be construed as offering more opportunities to women as they assume more agency and decision-making power. As Leder (2022) notes, 'the "Feminisation of Agriculture" discourse and related studies tend to work with contradictions, presenting migrants' wives as either empowered or vulnerable, as 'winners' due to increased decision-making opportunities, or 'losers' due to an increasing labour burden'.

In practice, the outcome of feminisation and the extent to which rural women are 'winners' or 'losers' will be partly shaped by how various policy instruments and institutions adapt. In that regard, several aspects of the study area need to be highlighted. First, women's ownership of agricultural land in West Bengal stands at about 5 per cent, while they make up almost half of the agricultural labour force (Valera et al., 2018). This is important because water rights are attached to land ownership in India, and ownership of the overlying land brings with it the right to access groundwater, provided the farmer can secure a pumping device. Second, many government support programmes are tied directly to land ownership. Accordingly, subsidies for accessing technologies, such as pumps, seeds and fertiliser, will seldom reach women because they are not registered as landowners.

Third, many smallholders are not financially able to own personal tube wells or pumps, even with state support, so water access is achieved by negotiations with pump owners—thus the creation of informal groundwater markets (Lountain et al., 2021). Only 6% of farmers in West Bengal had a pump set in 2013–2014; the other 94% rely on rental markets for pumping (Kishore, 2021). Informal groundwater markets can thus be considered an 'important institutional mechanism' (Mukherjee & Biswas, 2016) that has the potential to improve equity by extending groundwater access to poorer farmers, thereby increasing their agricultural production and improving their livelihood (Ananda & Aheeyar, 2019; Lountain et al., 2021; Mukherjee & Biswas, 2016).

Fourth, different irrigation pumping technologies are currently available to farmers in West Bengal, each with varying cost profiles (Table 1). These profiles manifest through the 'energy-irrigation nexus' (Bassi, 2015; Beaton et al., 2019; Daschowdhury et al., 2009; Mukherji, 2007; Shah et al., 2003) and can also have knock-on effects on how the groundwater markets function (Shah et al., 2003). Generally, groundwater irrigation is expensive in West Bengal because it relies primarily on diesel pump sets. Diesel is a much more expensive energy source than electricity, and the price of diesel has been rising rapidly since the Government of India withdrew the subsidy on diesel in October 2014 (Kishore, 2021). The most recent Minor Irrigation Census (2013–2014) showed that more than 76 per cent of the 0.43 million pumps in West Bengal were diesel-powered, compared with less than 30 per cent in the rest of India (Government of India, 2017). In addition to being more expensive to run, diesel pump sets are also less energy-efficient. Therefore, the difference in the cost per cubic meter of water pumped is even higher. Diesel is also a more expensive energy source for groundwater pumping, even without an electricity subsidy. While diesel pumps are clearly more expensive to run, the upfront purchase costs are low relative to electric pumps, and they are also easily transported between agricultural plots.

While the upfront cost of purchasing an electric pump is higher, the ongoing costs are generally lower. Nonetheless, government charging regimes for electricity usage can alter over time and, in turn, markedly change the running costs of electric pumps. In the 1970s, the Indian Government introduced an agricultural electricity subsidy that supplied farmers with unmetered electricity (Kishore, 2021; Shah et al., 2012). Prior to this, all state electricity boards charged for electricity based on metered tariffs. West Bengal instigated a flat-rate tariff for irrigation pumps based on horsepower in the 1980s. In 2007, the West Bengal State Government removed the flat-rate water tariff based on pump engine horsepower and reintroduced electric tubewell metering (Mukherji et al., 2009). Similarly, the removal of diesel subsidies after October 2014 has given rise to higher diesel costs, and this has significantly impacted dependent farmers (Kishore, 2021).

Another important dynamic relates to the costs of establishing a tubewell. Since 2011, farmers in West Bengal operating smaller pumps in districts with 'safe' groundwater have not been

TABLE 1 Comparison of pump running costs in West Bengal (Buisson et al., 2021).

Pump type	Running cost (Rs/per hour)
Diesel pump (day/night)	41.00
Electric pump (day)	26.00
Electric pump (night)	7.00

required to seek a permit to connect to the grid operated by the West Bengal State Electricity Distribution Company. In addition, the state's agriculture department introduced an INR 8000[2] one-off subsidy for these farmers, further defraying the purchase and set-up costs (Buisson et al., 2021). The subsidy does not have a gender criterion and is thus predominantly paid to men.

Solar powered pumps provide a possible alternative to traditional electric and diesel irrigation pumps, offering an appealing solution on environmental grounds. There are also benefits in terms of ease of operation and reduced variable costs (Closas and Rap, Closas & Rap, 2017; Mukherji, 2020). However, as is often the case with emerging technologies that seem to promise 'win-win' outcomes, evidence of 'success' can be slow to materialise (Khanna & Miao, 2022; Struik et al., 2014). Khanna and Miao (2022) note that adopting these technologies is not costless, and there is heterogeneity in site-specific costs and benefits from adoption. The main hurdle for solar pumps is the high capital cost, which is up to 15 times greater than for diesel pumps (Closas & Rap, 2017; Lountain et al., 2021; Pullenkav, 2017; Shah & Chowdhury, 2017). Although farmers are encouraged to adopt solar pumps through high capital subsidies of up to 90 per cent, the cost is still too high for many smallholders (Bassi, 2018). Furthermore, a formal land title, or proof of a lease agreement, is often needed to partake in schemes that support solar pumps, so tenants and female-headed households are generally excluded. For those who can access the necessary capital, Agrawal and Jain (2016) estimate that solar pumps are often preferred to grid-connected electric pumps because they overcome difficulties associated with unreliable centralised conventional electricity. Furthermore, the lifecycle cost of solar pumps is estimated at only half that of diesel pumps because they need minimal maintenance and are less likely to have high recurring costs (Kishore et al., 2017).

The different pump technologies have very different cost profiles, which can also potentially impact how groundwater is used and marketed. In addition, government policy that changes the affordability of different energy sources has repercussions for water markets. High upfront costs accompanied by low running costs lend themselves to increasing irrigation water supply in groundwater markets because it effectively spreads the cost of the pump across more sales of water. Thus, innovations such as solar pumps could have significant spillover effects on the groundwater market, given their cost characteristics—in effect, solar pumps should encourage pump owners to supply more water into the groundwater market, but this cannot be assured. Specific knowledge about what particular farmer cohorts value in pumping technologies and how they may or may not adopt and use technology is not widely understood. For example, providing subsidies to landowners (men) for electric or solar pumps may have quite different outcomes than the same subsidies made available to women farmers.

There are possible gender nuances here that warrant consideration. According to Patel (2012, p. 29), 'women farmers, above all, are India's poorest people', and increased participation by women in decision about technology adoption is one of the key indicators of gender empowerment in the agricultural sector (Aryal et al., 2020). With this in mind, we seek to better understand the relationships between gender, choice of technology (pumps) and its use, given the interplay of these variables and how they might impact agriculture, sustainable development and women's empowerment in West Bengal.

3 | METHOD

Technological adoption might vary between potential users, which might have flow-on effects on how a device is used. Against that background, we sought to understand how preferences for different pumping technologies might vary. Given that some of these technologies are not

[2] 1 INR equates about 0.0182205 AUD or 0.0119856 USD in December 2023.

widely used in West Bengal (e.g., solar), an approach was required that allowed for a degree of abstraction without imposing too great a cognitive burden on respondents. This section briefly describes and justifies the deployment of a paired comparison experiment.

3.1 | Paired comparison technique

Data collection aimed to obtain farmers' preferences for irrigation pump set characteristics in West Bengal, India. By understanding the preferences of different groups of farmers and comparing them against the government's current incentives, we sought to reflect on how present policies impact farmers and how adjustments might be needed to achieve different outcomes.

The data collection instrument for this research was a phone survey employing a paired comparison experiment. The paired comparison technique is a type of discrete choice experiment, a quantitative technique for eliciting preferences that can be used in the absence of revealed preference data (Mangham et al., 2009). Paired comparisons are one of the conjoint approaches to evaluating choice behaviour (Lockwood, 1999). Unlike other conjoint techniques, paired comparison is valued because of its inherent simplicity; the required judgements that must be made by respondents are limited, and this gives the experiment a sharper focus (Burton, 2003). This approach is particularly helpful if visual aids cannot be employed, as is the case with phone surveys.[3]

We can trace the paired comparison technique back to the seminal work of Louviere and Hensher (1982) and Louviere and Woodworth (1983). In paired comparison experiments, data are collected by presenting respondents with two choice options at a time and asking them to select one (Burton, 2003)—in this case, the option considered most important/preferred by the respondent. Paired comparison data have been used in multiple settings covering farmer behaviour, community attitudes, employment attractiveness, non-market valuation and sustainable land management (Behrens, 1986; Brown et al., 2021; Burton, 1972, 2003; Lockwood, 1999). Paired comparison has also been applied extensively in the field of psychology (Bradley & Terry, 1952; David, 1963; Davidson & Farquhar, 1976; Gulliksen, 1956; Peterson et al., 1996; Thurstone, 1927), where it has been used to find preferences within a given set of alternatives. Assuming that a continuous utility function can represent preferences, then random utility theory can be used to underpin the estimation of economic welfare measures from paired comparison data (Lockwood, 1999).

3.2 | Development of items for the paired comparison experiment

We generally followed the experimental design suggested by Hensher et al. (2015) and included interviews, focus group discussion and pre-testing prior to final data collection. The earlier phases all occurred pre-COVID-19 in 2019. This process aimed to reveal the relevant attributes and levels of the ‘product’, an irrigation pump set for farmers in West Bengal, India. An extensive literature review and discussion with experts in the region resulted in the development of a group of a priori attributes.

Interviews took place in August 2019 in New Delhi, India, with experts employed by the International Food Policy Research Institute, the Centre for Policy Research, Jawaharlal Nehru University and the Australian Centre for International Agricultural Research's Sustainable Development Investment Portfolio. Discussions with experts were open-ended and commenced at a high level to provide scope for participants to offer perspectives without leading.

[3]Fieldwork COVID-19 restrictions necessitated that a phone survey be used.

When discussing technology access, there was a consensus among the experts that recent solar pump subsidy programmes had achieved only limited success, especially in West Bengal. Although promoted to increase access to groundwater for smallholder farmers, there had been very little adoption, and this was attributed to the high upfront cost, even with the subsidy. Late subsidy repayments and low mobility of the pumps compared with diesel pump sets were also listed as barriers.

Semi-structured focus groups followed the expert interviews in September 2019, with men and women involved in agriculture in three regions in West Bengal—Tona Village, Bhangar and Raghunathpur Magrahat. These regions were chosen due to the activity of many (approximately 350) self-help groups, suggesting a degree of women's empowerment.

Local research assistants aided with this part of data collection, acting as guides, accompanying the research team and providing translation. Each focus group session began with an introduction defining the objectives of the research and the purpose of the focus meeting, namely, understanding participants' current groundwater irrigation practices, water use, opinions on different types of pumps, the subsidies available and improving females' access to technology. Care was taken to avoid discussing particular technologies—rather, the emphasis was on the generic factors that would make pumping groundwater a more attractive option for different groups of farmers.

3.3 | Survey and pre-testing

The final survey consisted of four main parts. Part A contained questions regarding the respondents' demographic and socio-economic status. In Part B, participants were asked about their influence in their community and their farm and household decision-making. Questions about pump sets currently used for irrigated farming were presented in Part C. Part D included questions to understand participants' preference for pumps, that is, the paired comparison experiment. The survey concluded with questions to measure the extent to which participants understood the survey.

The survey was pre-tested in October and November 2020. In the first instance, paper surveys were completed by farmers to trial the specific attributes, the response formats and the paired comparison choice sets. This pre-testing allowed further refinement around the wording of items to improve clarity. An online version of the survey was also pre-tested with experts familiar with agricultural and societal norms. Table 2 lists the final items used in the paired comparison part of the survey and the abbreviated attribute names used in the experiment.

3.4 | Paired comparison experimental design

The items in Table 1 gave rise to 45 unique pairwise combinations of attributes. As it is not feasible for all combinations to be presented to respondents, a design is needed to statistically structure the comparison 'attribute sets' to be seen by different respondents. *Sawtooth Software's Lighthouse Studio* programme created an algorithm to generate an optimal design. This method applies a cyclical algorithm that repeats the process 1000 times to select a combination of attributes that satisfies frequency balance, orthogonality, connectivity and positional balance criteria (see, e.g., Cooper et al., 2023; Khosroshahi et al., 2021). We selected an overall design that had 20 versions, each with four questions.

To reduce the time and cognitive demands on participants, each participant received a random subsample of only four pairwise comparisons. For each pair of attributes, participants were asked the question, 'Considering the following sets of items, please choose what you believe is the MOST important characteristic of a pump set in each pair' (Figure 1). For each set, participants

TABLE 2 Pump paired comparison attributes.

Number	Attribute	Abbreviation
1	The pump has affordable ongoing costs (i.e., I can pay the cost of running the pump)	Low ongoing costs
2	The pump can access deep water sources	Deep water
3	The pump can be connected to the electricity grid	Connects to grid
4	People in my area are already using that type of pump	Local use
5	The pump is portable (i.e., can be moved by a single person)	Portable
6	The pump can be used at any time of the day or night	Night use
7	I can make money from the pump when I'm not using it	Passive income
8	The pump has affordable upfront costs (i.e., I can pay the cost to purchase the pump)	Low upfront costs
9	The pump does not produce (too much) fumes and smoke	Low fumes/smoke
10	The pump can be maintained and repaired by myself or someone local	Local repairs

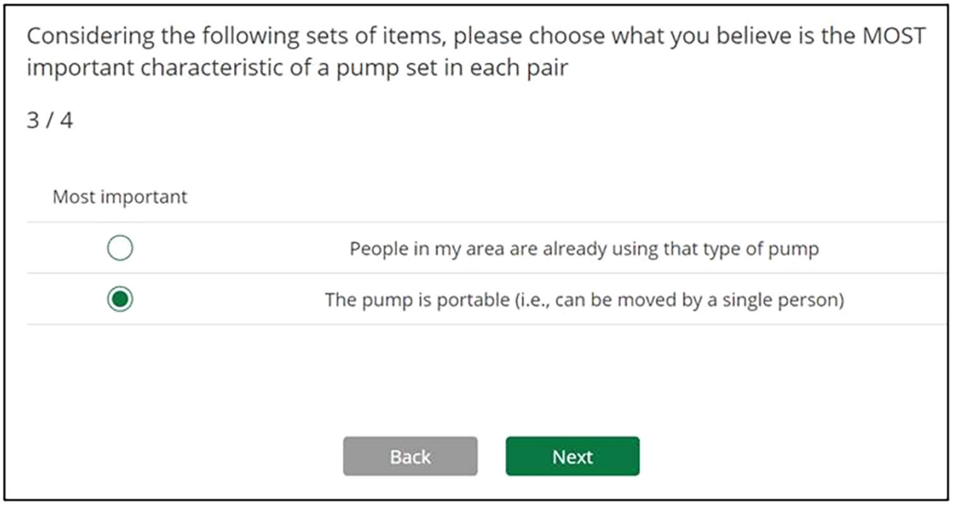

FIGURE 1 Example paired comparison choice set. [Colour figure can be viewed at wileyonlinelibrary.com]

could select only one option. Due to the random presentation of attribute pairs, some attributes may have been presented more than once by a participant, or not at all.

3.5 | Sample selection and survey administration

Interviews via mobile phones are a low-cost, rapid and safe way to collect data. During the COVID-19 pandemic, mobile phone surveys grew substantially in India (Nagpal et al., 2021). In this study, a local enumerator company was contracted to lead survey recruitment and data collection via mobile phone. Quotas were used to ensure representation by gender, tenant farmers and districts known for using a range of pump technologies, as well as different pump users and pump owners.

Enumerators recruited survey respondents from a database of participants who had completed a survey on irrigation facilities in 2020. Questions sometimes arise about the bias in sample estimates obtained through mobile phone surveys due to non-observation errors (Peytchev et al., 2011). These errors can arise due to differences between those who own and those who do not own mobile phones (non-coverage error; Barboni et al., 2018), as well as differences between those who respond and those who do not respond to surveys (non-response error; Mahfoud et al., 2015). While these surveys remain vulnerable to non-coverage and non-response errors, efforts were made in this study to limit the impact of bias, including identifying which population groups are excluded from samples, using protocols to minimise errors and the scaling of responses in analysis.

Data collection took place from late February to mid-March 2021. Enumerators phoned a participant, obtained participant consent, read the survey aloud and waited for the participant to respond, simultaneously entering responses into the online *Sawtooth Software*'s *Lighthouse Studio* platform. While the survey was developed in English, it was translated into the local language before deployment, to minimise translation variations across enumerators. The research team hosted the electronic survey data in Australia. The survey was initially piloted with a sample of 20 respondents to test the survey and software coding. Preliminary models were estimated on the pilot data to ensure the experimental design and survey instrument functioned appropriately.

The target sample was set at 300 respondents to allow sufficient exposure to the different pump attributes. Respondents were drawn from the districts of Cooch Behar, Bankura, Hooghly, Burdwan, North 24 Pargonas and South 24 Pargonas. To allow for appropriate variation, a maximum of 15 respondents per village were selected with varying types of irrigation sources with different kinds of pumps. The sample breakdown around farmer's access to water is outlined in Table 3. The sample breakdown by current pump use appears in Table 4.

Where respondents could not complete the paired comparisons in full, they were removed from the final sample for this section of the analysis. Enumerators reported that some respondents struggled with the abstract nature of the choices, because they had little familiarity with pump sets.

TABLE 3 Survey sample breakdown of how respondents access water for irrigation by gender.

Response	Female percentage of sample[a] ($n = 156$)	Male percentage of sample[a] ($n = 144$)	Total percentage of sample[a] ($n = 300$)
Own pump set/s	32.05	50.69	41.00
Jointly owned pump set/s	10.90	5.56	8.33
Community-owned pump set/s	7.69	11.11	9.33
Hired pump set/s	16.67	4.86	11.00
Buy water	31.41	26.39	28.99
Canal	1.28	1.39	1.33

[a]Respondents could select more than one response, that is, select all that apply.

TABLE 4 Survey sample breakdown by the main pump used by gender.

Respondent type	Female percentage of sample[a] ($n = 61$)	Male percentage of sample[a] ($n = 114$)	Percentage of sample[a] ($n = 175$)
Fuel (diesel/kerosene) pump	39.34	49.12	45.71
Electric pump	59.01	49.12	52.57
Solar pump (not connected to the grid)	1.64	0.88	1.14
Other	Nil	0.88	0.57

[a]Respondents could select more than one response, that is, select all that apply.

4 | RESULTS

4.1 | Logit model

The paired comparison data were analysed using a logit specification. Following this specification, we assume a latent utility function v for person n described over the 10 pump attributes J such that

$$v^*_{jn} = \beta_j X_j + \varepsilon_{jn} \quad (1)$$

where X_j is a vector of dummy variables, describing the attendance of an attribute and β_j is a vector of the associated utility weights. The results reported here are based on effects coding of the dummies such that the sum of all utility weights (parameters) is zero. We are unable to observe the exact utility of an individual; thus, a random error term ε is included to capture the unobservable component of the utility function.

Assuming this error process is described as Type II extreme value, the probability that individual n selects attribute j as the preferred option compared with attribute k is determined by:

$$P\eta\,(Y = j) = \frac{\exp\left(\lambda\beta_j X_j\right)}{\exp\left(\lambda\beta_j X_j\right) + \exp\left(\lambda\beta_k X_k\right)} \quad (2)$$

where λ is the scale coefficient, conventionally normalised to 1 for identification. Although estimated here as a logit model, it is equivalent to a conditional logit model with two alternatives.

4.2 | Logit results

In this section, we report the results of two logit models (Tables 5 and 6). We compare preferences for pump set attributes across gender and the energy source of an existing pump. We formally test for differences across farmer groups with log-likelihood ratio tests. The impact of other policy-relevant sociodemographic variables on preferences was also formally tested with log-likelihood ratio tests and found to be not significant.

It is also valuable to produce scaled parameters so that comparisons can be made across models. For each attribute, the probability that it will be selected as 'best' when compared to an 'average' attribute is calculated. Then, the resulting 10 probabilities are rescaled, so they sum to 100. Figures 2 and 3 report the resulting 'importance scores' related to each statistical model reported in Tables 4 and 5.

Table 5 displays the preferences for pump attributes by gender. The majority of female respondents did not identify as the head of their household but were involved in agriculture. Using a log-likelihood test, a formal test of whether preferences can be restricted to be the same across gender is rejected ($p < 0.001$). As such, we report estimates by gender. Significance tests evaluate whether the weight attached to the attribute differs from the average.

The model in Figure 2 (below) indicates that both men and women routinely select an alternative that has low ongoing costs. Interestingly, the upfront costs do not appear statistically significant in this model, supporting the view that respondents do not systematically select low upfront costs as a preferred attribute over others. Men in the sample selected away from those pumps that connect to the electricity grid and women were unlikely to be deterred by a pump set that was not widely used in the local area. Unlike their male counterparts, women were inclined to opt for a pump set that had capacity to generate income beyond its use on the individual's farm. The relative importance scores give an indication of the comparative importance of the attributes—this is one of the major advantages of this technique. For women, passive income has an importance score 2.4 times more than that of local use, while for men,

TABLE 5 Logit models of pump users by gender (effects coding).

Item	Females (n = 153)	Males (n = 144)	Total sample (n = 297)
1. Low ongoing costs	0.653***	0.584***	0.610*
	(0.178)	(0.188)	(0.128)
2. Deep water	0.090	−0.09	−0.009
	(0.157)	(0.160)	(1.111)
3. Connects to grid	−0.97	−0.557***	−0.316***
	(0.158)	(0.176)	(0.116)
4. Local use	−1.026***	0.152	−0.377***
	(0.186)	(0.159)	(0.116)
5. Portable	−0.011	−0.128	−0.640
	(0.167)	(0.181)	(0.121)
6. Night use	−0.092	−0.300	−0.216**
	(0.175)	(0.183)	(0.125)
7. Passive income	0.575***	−0.189	0.153
	(0.197)	(0.180)	(0.129)
8. Low upfront costs	0.189	0.012	0.099
	(0.175)	(0.182)	(0.124)
9. Low fumes/smoke	−0.365**	0.251	−0.556
	(0.174)	(0.170)	0.118
10. Local repairs	0.084	0.272	0.178*
	(0.186)	(0.190)	(0.132)
Choices	612	576	1188
Individuals	153	144	297
LL value	−396.40	−385.25	−800.55

Note: Standard errors in parentheses: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

the greatest difference in relative weight is between low ongoing costs and connection to the grid (1.8×).

A further test was conducted to evaluate whether there were differences in preference tied to land ownership types. When considering the four main types in the sample (landowners—37% of the total sample), tenants (8%), manage own farm and tenant farmer (12%), unpaid farm/household work (26%) and the null hypothesis that pump attribute preferences are the same could not be rejected ($p = 0.4656$). Other sociodemographic variables, including farm ownership, employment and pump features, such as who operated the pump and pump portability, were also tested but were found not to have a statistically significant impact on preferences.

Farmers who presently use pump sets that run on fossil fuels were also tested separately from those currently using electric pumps. Only two farmers were using solar pumps; as including these data would not change the results but may affect assumptions, they are excluded from the analysis to clarify interpretation. The results of the analysis appear in Table 6, with importance scores presented in Figure 3. The log-likelihood test indicates that the preferences of the two groups differ in systematic ways.

Those currently using a diesel-/kerosene-powered pump prefer devices that are attended by low ongoing costs. Perhaps not surprisingly, this group opts away from those pumps that can be connected to the grid, but favour those that are already widely used in the region and for which repairs are readily available. Those currently using an electric pump prefer earning

TABLE 6 Logit models, fossil fuel pump users and electric pump users (effects coding).

Item	Fossil fuel pump users ($n = 50$)	Electric pump users ($n = 53$)
1. Low ongoing costs	0.733**	0.521
	(0.326)	(0.309)
2. Deep water	−0.454	0.229
	(0.301)	(0.265)
3. Connects to grid	−2.001***	0.420
	(0.445)	(0.276)
4. Local use	1.080***	−1.519***
	(0.314)	(0.343)
5. Portable	0.236	−1.488***
	(0.311)	(0.431)
6. Night use	−0.146	0.609
	(0.382)	(0.319)
7. Passive income	−0.677	0.922**
	(0.350)	(0.362)
8. Low upfront costs	−0.604	0.167
	(0.369)	(0.315)
9. Low fumes/smoke	0.471	0.042
	(0.295)	(0.310)
10. Local repairs	1.361***	0.096
	(0.451)	(0.252)
Choices	200	212
Individuals	50	53
LL value	−108.35	−125.81

Note: Standard errors in parentheses: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

passive income from the device and systematically opt away from those that are used locally and are portable. Arguably, this is because the reliability of electric pumps is superior to that of diesel pumps; owners are less concerned with people in their community using the same kind of pump, that is, there is less likelihood of electric pumps needing repairs, spare parts or knowledge, which might be accessible from a neighbour. Similarly, portability is irrelevant to electric pump users, as electric pumps are generally not portable. Again, there is no evidence in these models to support the view that lower upfront costs are favoured systematically on average over other attributes.

5 | POLICY IMPLICATIONS

Groundwater irrigation and the reduction in rural poverty have been inextricably linked (Narayanamoorthy, 2007). Experts and parts of the literature have repeatedly emphasised that the high capital costs associated with pumps act as a barrier to smallholder ownership of pumps, and this has also provided a rationale for capital subsidies to increase pump ownership and thereby tackle poverty. At the same time, the national government's focus on increasing solar capabilities has led to heavily subsidised solar pumps. The *Pradhan Mantri Kisan Urja Suraksha Utthan Mahabhiyan* is a national solar scheme covering 90 per cent of the cost of a new solar pump

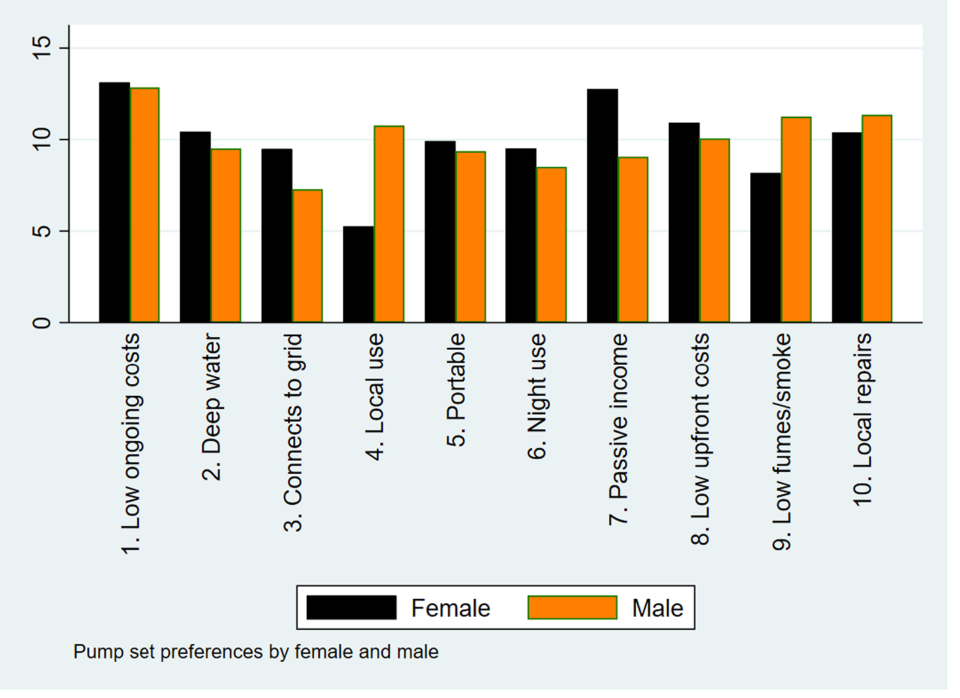

FIGURE 2 Comparing preferences by gender using importance scores. [Colour figure can be viewed at wileyonlinelibrary.com]

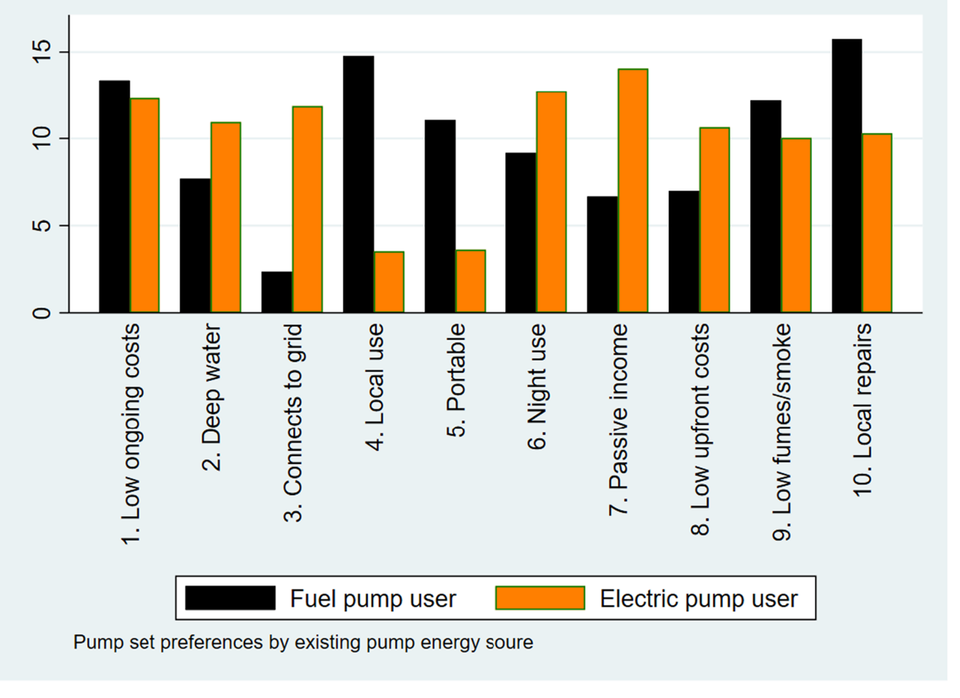

FIGURE 3 Comparing preferences by existing pump energy source. [Colour figure can be viewed at wileyonlinelibrary.com]

for eligible farmers. Apparently, this is still seen as unaffordable for most smallholders, and there has been minimal uptake in West Bengal to date (Bassi, 2018; Mukherji, 2020). Nonetheless, low adoption is not necessarily solely cost-related and could be driven by other factors, including behavioural factors and risk aversion (e.g., Ghimire et al., 2021).

There are at least some grounds for revisiting this policy rationale, given the data assembled for this project. Across all models, the low upfront cost of a pump set did not feature as a statistically significant variable for any of the groups analysed. Put differently, none of these groups showed a systematic preference for pumps that were cheaper to purchase and instal. In contrast, low ongoing costs were persistently chosen as a high priority by most farming groups. This might be explained by several phenomena. First, the current capital subsidies might be so well-targeted and widely known that farmers in the sample automatically discounted the capital cost of acquisition. Second, farmers who are involved in hiring pumps or accessing water by groundwater markets fail to see the link between the capital cost and their own costs, and these views dominate the sample. Third, farmers are more generally concerned with other attributes than the initial cost, and focussing on these has the potential to drive a wider uptake of pump ownership and use.

For the few farmers in West Bengal who have adopted solar pumps, there is a near-zero operational cost of accessing water (Kishore et al., 2017). High upfront costs but low running costs should lend themselves to increasing supply in groundwater markets, but the wider welfare impacts of this is an empirical issue worthy of closer scrutiny.

Other findings from the paired comparison experiment illustrate the importance of understanding pump preference heterogeneity among farmers. While lower ongoing cost is commonly preferred across all groups, there are other key and statistically significant differences. Specifically, we noted that the preference for earning income from the pump device, when not in use for their own agriculture, is significantly stronger among women. It was also a significant and positive attribute for those using electric pumps. This latter finding supports other studies that show that electric pump owners are more inclined to sell water to smaller landholders than those operating diesel pumps (Buisson et al., 2021). At a macrolevel, this might be presented as a pro-poor outcome resulting from the state government's 'One Time Assistance for Electrification of Agricultural Pump-sets', noting, however, that this invariably results in public transfers to larger farmers and men because of the way support is tied to land ownership.

This raises important questions about the flow-on effect on groundwater use if the government incentives to own pump sets are skewed in favour of some groups over others. For example, while we cannot say whether a stronger preference for a technology that can provide passive income will increase adoption among female farmers, we can speculate how greater ownership of pump sets by women may impact the use of groundwater pumps. It is possible, for instance, that if more women were in possession of a pump set, they would be more inclined than their male counterparts to be interested in the other opportunities to generate passive income from that ownership. This provides at least some basis for speculating how a gender-specific subsidy targeting female ownership of pump sets would translate to groundwater use, as opposed to the current model that does not include a gender criterion. There is at least some evidence in these data that increased ownership of a pump set by women might generate different types of pump use, given women's stronger preference for passive income. For example, these data raise questions about the extent to which interest might be raised around feed-in tariffs from solar pumps where more devices are owned by women.

Finally, these data also raise important questions about the trajectory for women as agriculture is increasingly feminised. At the outset, we noted that the likelihood of women benefiting from feminisation will be determined by the agency that accompanies change. As it stands, many policy mechanisms are in contrast to these changes and act against women benefiting from increased empowerment. The fact that government support for acquiring technologies is often tied to land ownership and the low rates of land ownership by women collectively reduces their access to technologies and resources (Mukhopadhyay et al., 2023, p. 6). In contrast, the data used in this study suggest that providing women access to pumping technologies will not only benefit them but also potentially result in different uses of that technology.

6 | CONCLUDING REMARKS

The data assembled by this project show that not all features of a pumping technology are equally valued by different farmer groups. It also brings into sharp relief the assumption that upfront cost is the main barrier to the broader ownership and use of pumps by farmers, especially given the policies already in place to deal with this concern. Previously, little was known about the specific features of pumping technology that particular farmer cohorts favour or how different cohorts might use a pump. Innovations around pumps and the energy sources for pumping can have significant spillover effects on the way pumps are used, and providing subsidies to landowners (generally males) for electric or solar pumps may have quite different outcomes relative to the same subsidies made available to women. Adding to this complexity is the way government subsidies are applied, being heavily contingent on land ownership.

Reducing the inequality in land ownership is unlikely to happen at the same rate as the feminisation of agriculture is occurring. The upshot is that women will not gain empowerment as the feminisation of agriculture occurs unless specific policies are chosen that directly support them and their access to technologies.

ACKNOWLEDGEMENTS

This work was supported by the Australian Centre for International Agricultural Research (ACIAR; LWR/2018/104). Open access publishing facilitated by University of South Australia, as part of the Wiley - University of South Australia agreement via the Council of Australian University Librarians.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Lountain, S., Cooper, B., Crase, L., Burton, M. & Rigby, D. (2024) Insights into preferences for irrigation pumps in West Bengal: An application of best-worst-scaling. *Australian Journal of Agricultural and Resource Economics*, 68, 349–365. Available from: https://doi.org/10.1111/1467-8489.12563