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Using rewards and penalties to incentivize energy and water saving behaviour in agriculture – Evidence from a choice experiment in Punjab

Sukhgeet Kaur
Michael G. Pollitt

Abstract

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JEL Classification

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Section 1: Introduction

The National Tariff Policy 2016 prescribes a levy of user charges and discourages giving free power to consumers. Rational and economic pricing of electricity is recommended as a tool for sustainable use of groundwater and energy conservation (National Tariff Policy 2016). The Electricity Act 2003 had mandated distribution utilities to supply electricity through installation of an accurate meter. These are sound prescriptions for the Northern Indian State of Punjab which supplies free electricity to agriculture pumps without the use of meters since 1997. Punjab faces acute groundwater crisis as successive governments have failed to limit extraction to the sustainable yield of aquifers. Out of 138 administrative blocks (blocks are development units of a district), 109 blocks are overexploited where groundwater extraction is more than 100 percent of the sustainable level. Free electricity encourages indiscriminate pumping and wasteful consumption besides lowering the water table level. As demand rises, it puts a strain on the electricity distribution network affecting the quality of supply. Further, the absence of verifiable energy accounting encourages inefficiency and theft of electricity. The unmetered and unverifiable agricultural power supply is regarded as the prime cause of the bankruptcy of distribution utilities in India (Shah et al., 2004). Delayed subsidy payment by the government deteriorates utilities' capabilities to maintain infrastructure and add to power generation capacity. The financial burden of subsidies on the government reduces the fiscal space for more important development goals. Therefore reform of the free electricity regime is good for the economy and the environment. A return to metered consumption and billing has the potential benefits of reducing subsidy burden, enforcing transmission and distribution efficiency in power utilities, and bringing about sustainable use of water and electricity in agriculture.

If the State Government wants to reimburse even part of the cost of electricity to a poor category of consumers the amount can be paid in cash or any other suitable way. The direct cash transfer of electricity subsidy as an income subsidy is expected to rationalize production decisions, reduce leakages, incentivize rational use of inputs, and contribute to the fixation of minimum agricultural support prices on a realistic basis (Johl et al., 2014). However, disbursing large upfront cash transfers is likely to burden the existing administrative system. Determining individual entitlement, disbursing the calculated amount and enforcing effective billing and collection of tariff revenue potentially imposes additional costs on the already burdened administrative system. Given the huge dependence of the agriculture economy on groundwater irrigation, withdrawal of free electricity initially appears inequitable, particularly because of its skewed distributional effect on poor farm households and is thereby politically difficult.

Arguably, metering and pricing of electricity – combined with direct income subsidies - is the best practice, however enforcement faces serious challenges. Barriers associated with political economy are the most difficult. Since the first-best economic solutions are unlikely to attract widespread political support and public acceptance, a second-best solution can be to offer an electricity entitlement and a cash incentive to set the incentive framework right in the electricity sector. The use of electricity quotas is considered an indirect way of controlling water pumping, which is relatively costless, easy, and equitable as compared to the abrupt withdrawal of subsidies (Zekri, 2008). There is empirical evidence of the use of incentives as a tool to promote environmentally significant decisions and behaviour among consumers (Bor et al., 2004). Behavioural interventions have been recognized to play an important role in gaining public support for subsidy reform (OECD 2012).

Drawing upon insights from behavioural approaches and international experience with innovative tariff structures, this paper applies a stated preference approach to examine farmers' preferences for replacement of free electricity policy with an annual limit of free electricity, the effect of a reward on inducing acceptance of a meter with an incentive and penalty scheme in encouraging the desired behavioural change to rationalize electricity and groundwater use. Variation in valuations by socio-economic, demographic, and regional profiles of farmers and the factors affecting their willingness to pay/accept decisions are also studied. The rationale for this study is that aligning tariff structures more closely with farmers' preferences is likely to reduce the barriers to metering and electricity pricing, and ultimately help in conserving natural resources, which face imminent danger with the present pattern of crop choices and electricity consumption in Punjab. This study is the first of its kind to get direct feedback from the farmers using a stated-preference experiment.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 discusses the discrete choice methodology. Section 4 presents the empirical results. Section 5 discusses the results and policy implications, and Section 6 offers conclusions.

Section 2: Review of literature

Farmers' attitudes are changing with increasing concerns about sustainable agriculture, but regulatory control may not work. Voluntary approaches involving incentives can be more effective in dealing with environmental problems than direct regulation. Interventions such as modifying market prices (through taxes or subsidies), offering conditional or unconditional financial incentives, and deploying non-monetary behavioural interventions or 'nudges' have been found to change energy-use behaviour (Sudarshan, 2017). Incentives have been used to encourage recycling (Bor et al., 2004; Timlett and Williams, 2008); motivate purchase of energy-efficient appliances (De et al., 2014; Stern, 1999), and reduce energy consumption (Bertoldi et al., 2013; Ito et al., 2018). Demand response programs award payments usually as a bill credit or discount rate for consumers' participation (Albadi and El-Saadany, 2007). Credits or bonus rewards are offered for installing electric meters (Xiqin et al., 2022, Ovo energy, 2020), compensation such as fixed monthly payment is offered for enrolling in demand response programs (Gagne et al., 2018), and financial rewards are offered to overcome customers' inertia toward dynamic pricing (Faruqui et al., 2010).

Another form of incentive based electricity product is to differentiate tariff levels according to consumption levels (Clements et al., 2013). Demand response tariffs apply financial incentives, in the form of rewards (e.g., discounts) or penalties (increasing price per kWh) to influence consumer electricity use (Mahmoodi et al., 2021). Rising block tariffs vary tariff according to consumption level (Sun and Lin 2013). Progressive tariffs penalize high consumption and electricity-saving feed-in-tariffs provide incentives to reduce the consumption of electricity (Prasanna et al., 2018).

Another voluntary approach empirically tested in Kukarwad, India was the use of compensation or 'financial benefit' for reduction of electricity use below a benchmark 'entitlement' and voluntary metering. This approach was drawn from the concept of energy conservation rebate (Wolak, 2010) and payment for ecosystem services. The results indicated that interest in participation was high, which led to an unprecedented voluntary shift to meter-based billing, but there was no major impact on water usage. Though, the voluntary nature of the approach was considered more acceptable to well owners than one based on regulation or direct pricing (Fishman et al., 2016). The authors suggested the need to test this voluntary approach of 'electricity entitlement' in other geographies to better understand its effectiveness in modifying water pumping behaviour.

Following this, a scheme titled 'Paani Bachao Paise Kamao' or PBPK (Save Water Earn Money) was introduced in the Indian State of Punjab in 2018. The scheme offers seasonal monthly electricity quota for farmers volunteering to install electric meters and a cash incentive of Rs. 4/kWh for using electricity less than quota.[3] The electricity quota is higher for the paddy season (from June to September) and lower for the non-paddy season (from October to May). The entitlement was worked out on the basis of previous year's electricity usage divided by the total tube well load on the feeder. The scheme could not reap the benefits owing to provisions of tariff-free electric power to irrigation sector in the state and other institutional factors. Further, there was no penalty on consumption in excess of the entitlement. Experts have argued that electricity quota can be made effective by charging a high price for electricity use beyond the allowed limit (Zekri, 2008). Accordingly this study motivated by the omission of an electricity tariff to penalize over-consumption in previous studies/pilots examined farmers' preferences for the twin elements of incentive to reward savings and disincentive or charging price for failure to limit consumption within entitlement.

[3]See: https://www.hindustantimes.com/cities/save-water-and-earn-money-pspcl-launches-voluntary-scheme-for-farmers/story-6CI0p45fKGRr4yKCzRMwMO.html

Further, one of the challenges of transition to metered consumption is to know the extent to which farmers are willing to pay for electricity. As is evident from Table 1, most published studies conducted on electricity consumers in India have focused on rural or urban consumers.

Table 1: Studies on WTP

Name of Author	Year, Place	Method	WTP
Gunatilake et al. (2012)	2083 rural households in Madhya Pradesh, (2012)	Bidding game	Rs. 219 ($2.56)
		Dichotomous Choice	Rs. 233 ($)
Kennedy et al. (2019)	8500 rural households in six states (2014-15)	Average WTP	Rs. 399 ($6.18)
		1 hour increase in total hours	Increase of Rs. 52 ($ 0.81)
		1 hour increase in nighttime hours	Increase of Rs. 136 ($2.12)
Bose and Shukla (2001)	950 farmers in Karnataka (1998-2000)		Rs 1.99 per kWh/Rs. 300/BHP
Blankenship et al. (2019)	1920 respondents in Uttar Pradesh (2017)	Rural and urban consumers	Varies between 0-200 rupees ($0-2.56)
Gill (2017)	Meta-analysis of WTP studies (2017)	Rural domestic consumer – for grid supporting all facilities	Rs. 290 per month ($ 3.71).
		Rural consumers off-grid basic lighting and mobile charging	Rs. 110 per month
Sagebiel and Rommel (2014)	Hyderabad	Domestic consumers	Low

It is noted that limited research has been undertaken to estimate willingness to pay for electricity for agricultural consumers in the Indian context. The current study fills this gap, being the first study to examine preferences for electricity entitlement and willingness to pay for metered consumption replacing the existing policy of free electricity for irrigation.

The study also examines the value farmers place on monetary incentive to save energy and disincentive to reduce high consumption beyond electricity entitlement.

Section 3: Discrete choice methodology

In this paper, discrete choice experiment was carried out with farmers in Punjab to identify preferences for free electricity entitlement and incentive/penalty to regulate consumption. Farmers received a discrete choice questionnaire that varied with respect to two attributes – annual limit of free electricity with cash incentive, and price of electricity. By varying the attribute levels, different alternatives were presented to the farmers. The price of electricity was varied to identify how farmers change their decisions about WTP accordingly.

A binary choice framework was selected as it reflects the current scenario where the choice is between opting for free electricity entitlement with metered option or to continue with the status quo option of free electricity policy. The three alternatives examined were, firstly, farmers' preferences were sought for meter installation and entitlement of free electricity instead of the prevailing policy of free and unmetered electricity. Secondly, farmers' responses for receiving cash incentive to save electricity and to pay a charge on consumption in excess of limit were examined to understand their effectiveness in modifying and incentivizing groundwater pumping and electricity consumption behaviour. Thirdly, the maximum price farmers are likely to pay for electricity per unit was determined to arrive at willingness to pay values. The value of each attribute and WTP was estimated using conditional and random logit model. Each respondent was presented with eight choice sets and prompted to indicate preference for accepting the policy alternative or the status quo option.

Description of Attributes and Levels

i. Annual limit of free electricity

Substitution of unmetered supply of free electricity by an entitlement of free electricity is expected to reduce pumping hours and consequently bring down monthly electricity consumption, besides discouraging theft and misappropriation of free farm power. As a first step, the baseline electricity entitlement was determined to reflect average electricity use by farmer. Estimating the minimum entitlement was difficult without availability of metered consumption data, except for data from some sample smart meters installed by Punjab State Power Corporation Limited. We relied upon past studies, and inputs given by farmers. Electricity consumption for pumping groundwater was calculated for an average farmer growing two crops – wheat and rice in a year. The prevailing seasonal supply schedule was obtained from the Punjab State Power Corporation Limited and cross-verified with the farmers to arrive at average pumping hours. The average connected load was multiplied by the estimated number of hours of pumping to arrive at two levels of annual limit of free electricity - 1500 kWh per acre and 1550 kWh per acre. While determining electricity entitlement, the variations in groundwater level, topography, soil, climate, cultivated crops etc. within the state were duly considered. Further, care was taken not to under-estimate annual limit of free electricity to ensure that genuine efforts are made by farmers to reduce electricity use.

A prerequisite to adoption of annual limit of free electricity is metering of agriculture pump connections. As regulatory policies to enforce meter installation are likely to face opposition, introduction of reward for meter installation was tested to understand whether this could serve as the starting point for reforming the prevailing regime of unmetered consumption in Punjab. The experiment offered a hypothetical reward of fixed payment linked to annual farm output to farmers volunteering for meter installation. The attribute of annual limit of free electricity was combined with reward payment of Rs. 20 ($0.25) per quintal of farm output. Assuming annual farm output of 48 quintals per acre, the reward scheme would generate an additional average income of Rs. 960 ($12.05) per acre. This amount was carefully calibrated to ensure that there is no loss and some measure of profit after payment of nominal electricity charge in case the actual consumption exceeded the annual limit of free electricity.

Monetary rebates and monetary motivations can result in significant curtailment in electricity consumption (Winett et al., 1978, Slavin et al., 1981). Rewards seem to have a positive effect on electricity use; households which receive rewards tend to save more than those who do not (Abrahamse et al., 2005). Drawing upon existing literature on the use of economic incentive to induce electricity conservation behaviour, a cash incentive was included with two levels - Rs. 2($0.02)/kWh and Rs. 3($0.03)/kWh for saving electricity within the entitlement of free electricity. This is similar to the cash incentive being offered in the existing scheme in Punjab. However the cash incentive is pegged at a lower level in this discrete choice experiment.

To summarize, the policy change alternative offered farmers two levels of entitlement of free electricity combined with a fixed reward payment for meter installation and two levels of cash incentive for saving electricity in the choice experiment. Farmers were informed that in case they did not want to opt for the policy change alternative, they could choose status quo and continue to receive unlimited and unmetered free electricity to pursue their present pattern of electricity consumption without participation in the reward scheme.

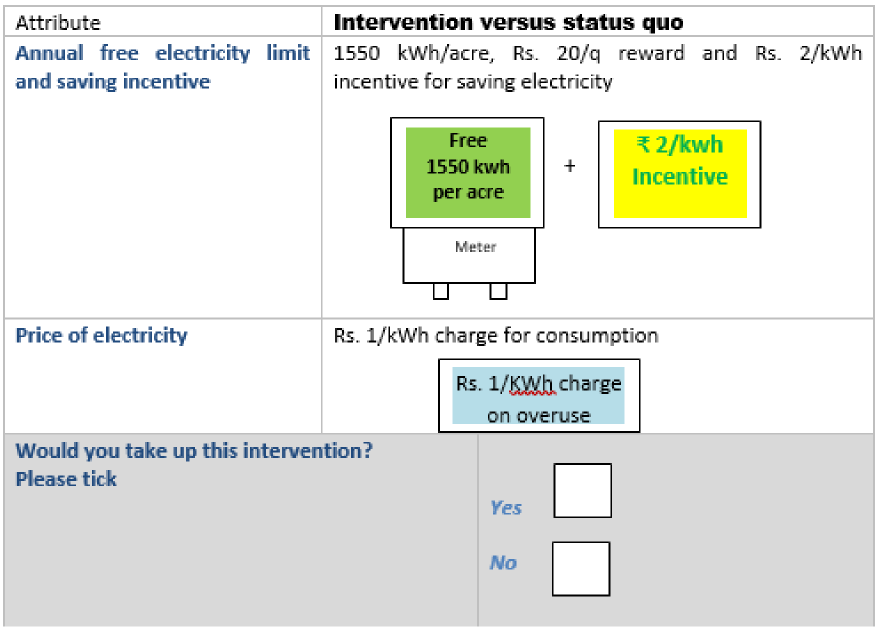
ii. Electricity Price

In a choice model, price is usually included as one of the attributes to arrive at willingness to pay values. Assuming a linear utility function, the implicit price of any attribute can be calculated by dividing the parameter estimate for that attribute by the parameter estimate of the price attribute to arrive at the willingness to pay value. The agriculture tariff determined by the Regulator was Rs. 5.66 per kWh (2020-21) in Punjab. Such a high charge may not be acceptable to all farmers. Therefore, a more reasonable level of electricity charge of Rs. 1($0.01)/kWh and Rs. 2($0.02)/kWh was selected as the price attribute in this choice experiment. Attributes and levels are presented in Table 2 and example of a choice set is shown in figure 1.

Table 2: Attributes and Levels

Attributes	Levels
1. Annual energy limit of free electricity and reward for conserving electricity	No energy limit/Free electricity without limit 1500 kWh/acre and Rs. 2/kWh incentive for saving electricity 1500 kWh/acre and Rs. 3/kWh incentive for saving electricity 1550 kWh/acre and Rs. 2/kWh incentive for saving electricity 1550 kWh/acre and Rs. 3/kWh incentive for saving electricity
3. Price of Electricity beyond limit	No electricity tariff Rs.1/kWh Rs.2/kWh

Figure 1: Example Choice Set



Before offering a hypothetical package of entitlement and reward penalty scheme which does not yet exist, it is crucial to understand how people would react to a new arrangement in terms of comprehension, relevance, and credibility. As the first step, scoping trips to major districts in Punjab were undertaken in 2019 and 2020 to collect basic information and interact with farmers. Interviews were held with farmers to elicit their views about electricity supply, problems faced due to uncertain supply and nighttime supply, power theft, political and cultural factors, and approximate level of electricity charge farmers may be willing to pay. Information on feeder segregation, seasonal supply schedules, cropping patterns, tariff structures, water-saving technologies, and state initiatives was collected from the relevant authorities during this visit. Discussions were held with officials of Punjab State Power Corporation, Punjab State Electricity Regulatory Commission, Department of Agriculture and Water Resources to understand the power distribution system, power demand, concerns from supply-side & regulatory issues, etc. Interactions were also held with experts in Punjab Agriculture University and research bodies. About eight to ten people took part in each discussion. Farmers' feedback received during the interactions and visits to electric feeders gave guidance about the likely incentive levels and electricity rates to be included in the experiment. This formed the basis of drafting the preliminary questionnaire.

Attribute levels were identified and choice sets were generated with the help of Ngene software (Ngene 2021). Since the full-factorial design is demanding on the respondents, fractional factorial design was generated to produce 8 choice situations with the help of the Ngene software. The selected design met the criteria of low correlation between attribute levels, minimal overlap, level balance and low D-error. The preliminary set of attributes and levels were piloted for further refinement. A second round of interviews was conducted in September 2021 to pre-test the questionnaire. After observing the responses and taking feedback of farmers, the choice sets were revised to incorporate their comments. Subsequently, the main survey was conducted from November 2021 to March 2022. Interviews were held with 859 farmers in twenty districts of Punjab, including Moga, Ludhiana, Jalandhar, Kapurthala, Sangrur, Patiala, Bhatinda, Faridkot, Ferozepur, Gurdaspur, Amritsar, Ropar, SAS Nagar, Tarn Taran, Fazilka, Malerkotla, Muktsar, Hoshiarpur, Fatehgarh Sahib, and Barnala districts. The experiment yielded 6872 observations. At the beginning of each interview, the attributes and the associated levels were clearly articulated. A detailed explanatory handout was read out to the respondents describing the study and its purpose. Prior verbal consent of respondents was obtained and confidentiality was assured. Farmers' views were ascertained about electricity service, groundwater crisis, climate change, etc. to warm up and get them involved in the survey before asking discrete choice questions. They were asked to share their views about the development priorities to sensitize them about the importance of other developmental initiatives apart from policy of free electricity supply. They were cautioned against seeking higher incentives which the government may not be able to provide. External validity is a challenge in discrete choice experiments. However, farmers' acquaintance with the ongoing PBPK scheme in Punjab helped overcome this challenge. In-person interview mode of survey administration was chosen. To minimize interviewer bias, the author administered the main survey questions.

Model Specification

A binary logit model was used to determine the probability that a farmer would accept the annual limit of free electricity and incentive to save electricity. Following Louviere et al., (2000), a random utility model is defined as:

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (1)$$
$$i = 1, \dots . I \text{ and } n = 1, \dots \dots N,$$

where U_{in} is the nth farmer's expected utility accruing from choosing alternative i, V_{in} being the deterministic portion of utility and ε_{in} is the stochastic component. The probability that n chooses i is:

$$P_{ni} = P_r [U_{in} \geq U_{jn}]$$

$$P_{ni} = [\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}] \qquad (2)$$
$$\text{For all } i, j \in C$$

where C_n is the choice set for farmer n [C_n = {i, j} = {Accept, Don't Accept}]

Assuming that V_{in} and V_{jn} are linear in their parameters, the indirect utility function of alternative I (I =1) for respondent n to be estimated is given by:

$$Adoption_{in} = \beta_0 + \beta_1 x Limit1500_{2in} + \beta_2 x\, Limit1500_{3in} + \beta_3\, x\, Limit1550_{2in} + \beta_4 x\, Limit1550_{3in} + \beta_5\, x\, Electriccharge_{1in} + \varepsilon_{in} \qquad (3)$$

Where $Adoption_{in}$ denotes the deterministic part of utility accrued by farmer. The annual limit of free electricity and saving incentive attribute levels were denoted by $Limit1500_2$, $Limit1500_3$, $Limit1550_2$, $Limit1550_3$ and associated sensitivity parameters were β_1, β_2, β_3 and β_4. Similarly, price of electricity was denoted by $Electriccharge_1$ and the associated sensitivity parameter was β_5. β_0 was a constant reflecting respondents' preference for acceptance and ε_{in} was the random error term. The attribute of annual free electricity limit and incentive for saving electricity was indicated by dummy variable. The base level was defined as the level with the smallest annual limit of free electricity and lowest cash incentive. The price attribute was included as a continuous monetary variable.

Estimation strategy

A conditional logit model and random effects probit model was applied to estimate respondent preferences for annual limit of free electricity and cash incentive for saving electricity and electricity price attribute. The random effects probit model was applied as it is considered a more appropriate model for analyzing data with multiple observations from one respondent. Further, it relaxes the restrictive assumption of IIA imposed by conditional logit model. The model is specified to take account of the potential correlation between observations from each respondent (Bryan et al., 1998)

$$\Delta V = \alpha_1 xLimit + \alpha_2 xPrice + \theta + \varepsilon \qquad (4)$$

where ΔV is the change in utility in choosing annual limit of free electricity and cash incentive, 'Limit' is the difference in the level of annual limit of free electricity and cash incentive and 'Price' is the difference in the price of electricity. α_1 and α_2 are the parameters of the model to be estimated. ΔV is a binary variable, taking the value of 0 if the individual chooses unmetered consumption and 1 if the individual chooses annual limit of free electricity and cash incentive. θ is the error term due to differences amongst observations and ε is the error term due to differences among respondents. Corr [θ, ε} = ρ and ρ takes account of the potential correlation between observations from any one individual. α_j / α_2 (j = 1, 2, 3) is an estimate of the willingness to pay (Ryan and Hughes, 1997, Ryan et al., 2007).

Dummy variables were incorporated to account for non-linearities and estimate effect of each level. Limit 1500_3 specifies annual limit of 1500 kWh/acre and cash incentive of Rs. 3/kWh; Limit 1550_2 specifies annual limit of 1550 kWh/acre and cash incentive of Rs. 2/kWh and Limit 1550_3 specifies annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh.

Section 4: Empirical results

The results of the random effects probit and conditional logit models show statistically significant coefficients in Table 3. Farmers' preferences for various attributes are in the anticipated direction. Farmers' preferences increase in proportion to the annual limit of free electricity and cash incentive. There is clear preference for higher annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh followed by entitlement of 1550 kWh/acre limit and incentive of Rs. 2/kWh. The valuation for annual limit of 1500 kWh/acre with incentive of Rs. 3/kWh was lower. Ceteris paribus, these estimates suggest that higher saving incentive and bigger annual limit of free electricity units increases farmers' utility. The negative coefficient on Price indicates that, other things being equal, if there was a charge on electricity, farmers are more likely to choose the status quo. The random effects probit and conditional logit models are well specified. The overall goodness of fit indicated by pseudo-R-square value was 0.24.

Table 3: Estimation results

Attribute	Coefficient	Std. Error	Coefficient	Std. Error
	Random Effects Probit		Conditional logit	
Limit 1500_3	.8553***	.0481	1.4669***	.0840
Limit 1550_2	1.488***	.0496	2.5013***	.0882
Limit 1550_3	1.573***	.0499	2.6543***	.0894
Price	-.03411***	.0330	-0.5815***	.0555
Cons	-0.4278	.0599		
lnsig2u	-2.663	.2302		
sigma_u	0.2640	.0303		
Rho	0.0651	.0140		
Log likelihood	-3997.37		-2482	
Pseudo R^2	0.16		0.24	
N	6872		6872	

***$p < 0.05$

Willingness to pay: The model coefficients are used to derive willingness to pay values and assess the extent of preferences for electricity limit with metered consumption from the discrete choice model. WTP values are estimated by the following formula (Ryan et al., 2012):

$$Willingness\ to\ pay = \frac{\beta Limit}{\beta ElectR\text{te}}$$

where *Limit* refers to annual limit of free electricity unit and incentive and *ElecRte* refers to the price of electricity. Willingness to pay values are presented in Table 4 below. The WTP values are Rs. 4.60/kWh for free electricity limit of 1550 kWh/acre with 3/kWh cash incentive and Rs. 2.50 per unit for lower limit of 1500 kWh/acre and Rs. 3/kWh incentive. The results of the analysis showed that farmers are willing to pay for electricity. This indicates an opportunity to wean farmers away from the policy of delivery of free electricity. The similarity of values in the logit and probit models suggests a high level of convergent validity between the two models. The estimates are statistically significant.

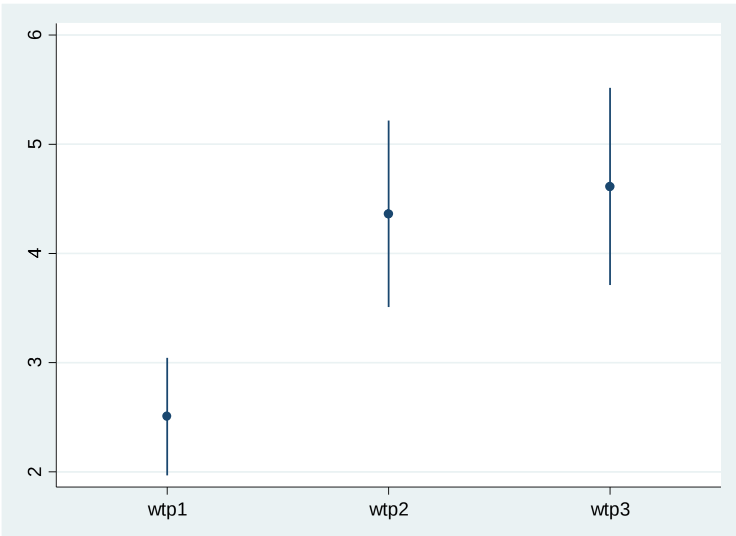
Table 4: Willingness to pay/willingness to accept

WTP/WTA	Random effects probit	Conditional logit
WTP/WTA1 Limit 1500_3	2.50***	2.52***
WTP/WTA2 Limit 1550_2	4.36***	4.30***
WTP/WTA3 Limit 1550_3	4.61***	4.56***

***p < 0.05

Figure 2 shows the WTP/WTA estimates and 95% confidence intervals for the three attribute levels of annual energy limit and cash incentive.

Figure 2: Willingness to pay estimates and 95% confidence intervals



Choice probabilities

A useful finding of discrete choice model is to examine the probability of choosing a given option as the levels of the attributes are changed. Uptake probabilities were calculated based on the preference estimates in Table 5. The predicted adoption rate ranged from 69 percent for lower free electricity limit and 84 percent for higher free electricity limit.

Table 5: Predicted probabilities

Attribute	Coef. (Std. Err.)
	Probit
Limit1500_3	0.6949*** (0.0092)
Limit1550_2	0.8275*** (0.0077)
Limit1550_3	.8446*** (0.0073)

***p < 0.05

Change in probability

The change in probability of accepting the annual limit of 1550 kWh/acre with cash incentive of Rs. 2/kWh and Rs. 3/kWh respectively with reference to the lower limit of 1500 kWh/acre and cash incentive of Rs. 3/kWh is simulated in Table 6 below. The results demonstrate that probability increases by 30.6 percent for free limit of 1550 kWh/acre and cash incentive of Rs.2/kWh and increases by 34.4 percent for annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh. It indicates that increasing the annual energy limit has a relatively greater impact on promoting acceptance than increase in the cash incentive.

Table 6: Change in probability

Attribute	Coef. (Std. Err.)
	Probit
Limit1550_2	0.3064*** (0.0204)
Limit1550_3	0.3444*** (0.0200)

***p < 0.05

Comparison of coefficients between the regions

The name Punjab is made of two words Punj (Five) + Aab (Water) i.e. land of five rivers. These five rivers of Punjab are Sutlej, Beas, Ravi, Chenab, and Jhelum. Only Sutlej, Ravi and Beas rivers flow in today's Punjab. The other two rivers are now in the state of Punjab, situated in Pakistan. The Punjab State is geographically divided into three regions: Majha, Doaba and Malwa. Majha area lies between rivers Ravi, Beas, and Sutlej and is called the heartland of Punjab. Doaba is the region of Punjab between the rivers Beas and Sutlej. The word Doaba translates to 'land between two rivers'. It is one of the most fertile regions of the world and was the center of the Green Revolution in India. Malwa is the region to the south of river Sutlej and makes up a large part of the state comprising more than eleven districts.

A comparison of preference behaviour between farmers in the three regions of Majha, Malwa and Doaba in Table 7 shows that the Doaba region of Punjab shows the highest preference for accepting free electricity limit and cash incentive. The region also demonstrates the smallest negative preferences for paying for consumption in excess of the entitlement.

Table 7: Estimation results - region-wise

Attribute	Majha	Malwa	Doaba
Limit 1500_3	0.8137***	0.8553***	0.9138***
	1.4040***	1.4596***	1.5914***
Limit 1550_2	1.4563***	1.4790***	1.5765***
	2.4511***	2.4799***	2.6706***
Limit 1550_3	1.5975***	1.5539***	1.6294***
	2.6955***	2.6169***	2.7683***
Price of electricity	-0.3294***	-0.3586***	-0.2812***
	-0.5617***	-0.6103***	-0.4844***

***$p < 0.05$

Non-linear effects through interaction

Segmentation analysis has been conducted to determine the effect of socio-demographic characteristics on farmers' preferences for the different attributes. Table 10 in the Appendix shows results of the interaction terms of the attribute levels with age, education, connected load, tube well ownership and land size. Education has a positive impact on the preference for moving away from status quo. Matriculate or school pass farmers are more likely to significantly prefer annual limit of 1550 kWh/acre of free electricity and cash incentive of Rs. 2/kWh. However farmers with education above graduation are significantly less likely to accept a charge on electricity. Matriculate farmers do not have negative preferences for paying for electricity, although the result is not significant. The findings show that marginal farmers are more likely to stay at status quo level at lower annual entitlements.

Section 5: Discussion

The results of this discrete choice experiment reveal significant coefficients for attributes of annual limit of free electricity and cash incentive and higher valuations for higher limits and incentives. There is significant heterogeneity in the valuations for the attributes. A moderate level of annual free limit of 1550 kWh per-acre and cash incentive of Rs. 2/kWh is acceptable to about 70 percent of the farmers. The preference coefficients show acceptance for paying electricity charge of Rs. 1/kWh on consumption in excess of free limit. Higher charge of Rs. 2/kWh on excess consumption lowers the acceptance rate. The acceptance rate is 23 percent for 1500 kWh/acre free limit and cash incentive of Rs. 3/kWh and 50 percent for 1550 kWh/acre and cash incentive of Rs. 2/kWh at the higher price. The acceptance rate improves to 84 percent for 1550 kWh/acre free limit and cash incentive of Rs. 3/kWh at the same charge. These results broadly concur with empirical evidence of preference for incentive to motivate energy savings and the positive effect of introducing electricity entitlements (Fishman et al., 2016).

Table 8: Acceptance rate of various bundles

Entitlement	Incentive	Penalty	Acceptance rate
1500 kWh/acre	+3/kWh	-1/kWh	27%
1550 kWh/acre	+2/kWh	-1/kWh	70%
1550 kWh/acre	+3/kWh	-1/kWh	84%
1500 kWh/acre	+3/kWh	-2/kWh	23%
1550 kWh/acre	+2/kWh	-2/kWh	50%
1550 kWh/acre	+3/kWh	-2/kWh	82%

This research makes a significant contribution to the literature. First, combining free electricity entitlement and cash incentive for saving electricity can induce adoption of metered consumption. However, higher annual limit of free electricity constitutes a more important attribute than cash incentive. A necessary condition is entitlement of free units sufficient to meet farmers' minimum irrigation needs. Second, there are potential benefits from the implementation of a compensation incentive to encourage reduction in average consumption and charging a price beyond the limit to enhance responsiveness to the free electricity limit. A cash incentive for saving electricity increases the marginal returns of not mining water and raises the opportunity cost of pumping groundwater, which functions as de-facto regulation of groundwater use. Third, pricing electricity (even at a nominal variable rate) could be made acceptable by offering a higher annual free electricity limit and cash incentive. Fourth, shifting the subsidy from electricity to an incentive for reducing consumption can drive behavioural change to save water consciously. This information is very important in light of intensified concerns about rapid deterioration in water table levels. Promotion of water-saving technologies may fail to realize full potential without the introduction of incentives for conservation of groundwater or the electricity used for pumping it, through the use of marginal pricing (even at rates that are below socially optimal levels) or other mechanisms to limit the expansion of irrigation (Fishman 2015). Fifth, the incentive could be financed from the electricity subsidy saved. A cost-benefit analysis is conducted to evaluate the economic viability of shifting state support from a subsidy for electricity use to an incentive for conserving electricity and groundwater.

Average annual consumption of a farmer is assumed to be 2090 kWh per acre. This is calculated by averaging the highest and lowest electricity entitlement under the existing Pani Bachao Paise Kumao scheme. There is likely to be saving of 540 kWh per acre with annual limit of 1550 kWh per acre, which amounts to gross saving of electricity subsidy of $38.37 per acre and net saving of $26.32 per acre after deducting the cost of reward for meter installation. Calculated for the entire state, this strategy could save about $267.86 million annually.

The saving of electricity subsidy and groundwater is likely to be higher when consumption is averaged over 10 HP motor and 25 HP motor on the basis of actual supply schedules, though there may be some variation due to local interruptions. The annual saving of electricity subsidy is around $1236.5 by shifting to an annual limit of 1550 kWh/acre. The cash incentive offered for reducing consumption therefore can potentially be financed out of the savings from reduced burden of electricity subsidy.

Table 9: Cost Benefit Analysis – Saving of electricity and water per acre

For the Economy		
Current average unmetered supply of free electricity*	kWh	2090
Annual limit of free electricity	kWh	1550
Saving in electricity consumption	kWh	540
Saving in electricity subsidy	$	38.37
Reward for meter installation (Rs.20/q)	$	12.05
Net saving in electricity subsidy	$	26.32
For the Environment		
Groundwater savings	KL	3085.4
Carbon savings	tonnes	0.4428

*Average of highest and lowest entitlement for 10 HP and 25 HP pump under existing PBPK scheme; Rs. 79.64=$

This repurposing of state support presupposes provision of reliable and stable electricity. Typically, supply quality is defined as, "better voltage, fewer fluctuations, longer hours of supply, and daytime supply," (Gulati and Pahuja, 2012, page 26). Strictly scheduled supply at preannounced hours is expected to discourage wasteful behaviour (Sidhu et al., 2020). Risk-averse farmers are likely to over-irrigate their fields if supply is uncertain. Tariff increases concomitant with improvements in the quality of service have resulted in durable tariff reform in other countries (Clements et al., 2013). The survey results indicate that the same is likely to hold true for Punjab.

Section 6: Conclusion

Free supply of electricity to agriculture is credited with making an essential service affordable for a broad base of farm households and contributing to increased agricultural yields. As fiscal resources become scarce and environmental costs rise, the central policy question is whether these subsidies can be scaled back or overhauled in their design, given that they are already in place. As regulations are likely to be unpopular, indirect measures such as replacing free power with an annual limit of free electricity and cash incentives are likely to be effective in reducing power consumption and groundwater withdrawals. However, before introducing annual energy limits and incentive-based demand response programs, there is a need to test farmers' willingness for the reoriented state support. This study examines willingness and interest of farmers to participate in an incentive scheme combined with a metering option based on a discrete choice experiment conducted with 859 farmers in Punjab in 2021-22. The major finding is that farmers are willing to voluntarily move away from unmetered consumption to meter installation with the inducement of cash incentive to save electricity combined with annual limit of free electricity sufficient to meet current irrigation requirements.

The random effects probit and conditional logit models applied in this study evaluate preference heterogeneity for electricity entitlement, economic incentive for saving electricity, and pricing electricity. This study highlights the acceptance of both carrot and stick policies for motivating behavioural change in Punjab. An annual limit of 1550 kWh/acre units of free electricity is acceptable by 84 percent of the sample farmers. It is also found that farmers are likely to have higher acceptance for an annual energy limit when supplemented by cash incentive to reduce consumption within the entitlement. The combined incentive-penalty based scheme is effective in inducing greater participation and acceptance of the entitlement as an alternative to disbursement of the current electricity subsidy. The results show that moderate rates of cash incentive and electricity charge are acceptable to about 71 percent of the respondent farmers. The preference for incentive demonstrates the saving intention of farmers and shows that cash incentive can energize behaviour towards saving electricity. The results illustrate the acceptance of a variable electricity charge on consumption beyond the annual free limit. Further, the willingness to pay could be increased by offering a higher annual limit of free electricity. A variable charge on electricity above the limit is likely to make farmers aware of the real cost of power and water and induce them to economize on its use.

The results of the choice model report willingness to pay for electricity of Punjab farmers. It is found that farmers are willing to sacrifice Rs. 4.30($0.05)/kWh for 1550 kWh/acre limit of free electricity and cash incentive of Rs. 2/kWh. They are willing to sacrifice Rs. 2.5(0.03)/kWh for 1500 kWh/acre and Rs. 3/kWh incentive for saving electricity. These findings can be useful in designing new schemes of subsidy disbursement which can wean away farmers from unmetered consumption. It is observed that farmers in Punjab's most fertile region, the Doaba region are more likely to accept an entitlement of free electricity and a cash incentive to adopt energy-saving behaviour. Educated farmers are more likely to value the annual free limit combined with an incentive for reducing consumption.

Imposing a cap on free electricity consumed by a large farmer who may be receiving 40 times the subsidy given to a marginal farmer has the substantial potential of reducing the burden of electricity subsidies and easing pressure on aquifers. The resultant savings in electricity subsidy could compensate for the additional costs incurred in financing rewards for adopting energy-saving behaviour. The results of this study can be taken as a reference for formulating future policies and programs such as raising education levels and disseminating information to increase uptake of meter installation.

This is the first stated preference choice experiment that has involved the direct elicitation of the preferences of Punjab farmers. However, decisions taken by farmers are invariably more complex than the scope of this choice experiment. The validity of the preference model is restricted by the number of attributes and levels and their interpretation by individual farmers. There can be other influences on participation rates or the 'hypothetical bias'. The model could be extended in future research to account for precise real-time individual electricity consumption, analyze the influence of other incentive instruments and allow for diverse spatial and socioeconomic effects. The present study is valuable as these findings can translate to a promising intervention strategy to rationalize electricity consumption in Punjab agriculture. The econometric results serve as a first useful indicator of nudging farmers to more often choose a metered electricity option, which may not do away with subsidies, but can certainly complement efforts to contain electricity subsidies and groundwater extraction, and effectively introduce a positive price for electricity and for ground water pumping.

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Appendix

Table 10: Interaction terms

	Conditional logit model		Random effects probit model	
Interaction term	Coef.	Std. Err.	Coef.	Std. Err.
Limit1500_3				
Single	0.1345	0.15	-.2709	.2935
Multiple	0.1142	0.15	-.2081	.2870
Limit1550_2				
Single	-0.1372	0.15	-.2709	.2935
Multiple	-0.0786	0.15	-.2081	.2870
Limit1550_3				
Single	0.1417	0.15	.1866	.2925
Multiple	0.0592	0.15	.0282	.2846
Price				
Single	-0.0472	0.1	-.0679	.1812
Multiple	-0.1418	0.1	-.2294	.1776
Limit1500_3				
Marginal	-.0389	.20	-.1989	.3711
Small	.2343	.18	.3258	.3440
Semi medium	.1448	.18	.1300	.3324
Medium	.0867	.18	.0422	.3400
Large	.2326	.22	.3652	.4045
Limit1550_2				
Marginal	.0617	.21	-.1299	.3942
Small	.0378	.19	-.0584	.3632
Semi medium	-.1709	.18	-.4448	.3505
Medium	.1361	.19	.07230	.3624
Large	-.0303	.22	-.1099	.4251
Limit1550_3				
Marginal	.1884	.21	.0806	.3927
Small	.3006	.19	.3704	.3629
Semi medium	.1385	.18	.0582	.3500
Medium	.1645	.19	.1238	.3585

Large	.1241	.22	.1478	.4245
Price				
Marginal	-.0888	.14	-.1215	.2471
Small	.0197	.13	.0552	.2229
Semi medium	-.1407	.12	-.2062	.2177
Medium	-.1456	.13	-.2293	.2240
Large	-.0348	.15	-.0465	.2602
Limit1500_3				
Low load	0.0621	.14	.08587	.2522
Medium load	-0.0431	.15	-.1230	.2710
High load	-0.0114	.22	-.1436	.3845
Limit1550_2				
Low load	-0.1752	0.14	-.3085	.2677
Medium load	-0.0683	0.15	-.1938	.2884
High load	-0.1974	0.23	-.4538	.4148
Limit1550_3				
Low load	0.1805	0.14	.2799	.2660
Medium load	0.0511	01.5	.0075	.2850
High load	-0.2409	0.22	-.5109	.4038
Price				
Low load	-0.0540	0.09	-.0828	.1650
Medium load	-0.0523	0.10	-.0758	.1785
High load	-0.0275	0.15	-.0428	.2664
Limit1500_3				
Upto matriculate	0.1424	0.14	.2804	.2598
Upto Graduate	0.1626	0.15	.2727	.2670
Above Graduate	0.2982	0.28	.4663	.4971
Limit1550_2				
Upto matriculate	0.2574*	0.15	.4897*	.2711
Upto Graduate	0.1562	0.15	.2489	.2770
Above Graduate	0.4693	0.29	.7326	.5222
Limit1550_3				
Upto matriculate	0.1480	0.15	.3094	.2763
Upto Graduate	0.1603	0.15	.2514	.2833
Above Graduate	0.1772	0.28	.2749	.5183

Price				
Upto matriculate	0.0042	0.10	-.0064	.1749
Upto Graduate	-0.0170	0.10	-.0259	.1789
Above Graduate	-0.3507*	0.19	-.5471*	.3220

*p<0.1