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Stabilization of prices has been an important element of achieving food price stability in most countries — both developing and developed, including India. In this paper, we re-think the extension of the price stabilization as a compensation strategy to stimulate change in favour of low-water crops in Punjab. Groundwater facilitated impressive agricultural production, particularly record increases in wheat and rice productivity in Punjab, but also accelerated depletion of aquifers. Free electricity and negligible pumping costs aggravated the problem and the resultant policy failure encouraged unregulated use of groundwater, lower relative profitability of water efficient crops and a shift in favour of water intensive crops. Questions are now being raised about the sustainability of this intensive agriculture strategy. The rapidly depleting water table level and soil deterioration from overuse of fertilizers and pesticides are attributed to farmers' preference for high-water rice variety. Drawing from the Payment for Ecosystem Services scheme, this stated preference experiment investigates farmers' preferences to change high-water rice variety by low-water variety with compensatory payments. Results show that majority of farmers are willing to accept compensation for substitution by low-water intensive rice variety. In addition, the scheme can be accompanied by significant willingness to pay (WTP) for electricity, but the WTP is contingent upon the nature of electricity charge.

Keywords

Agriculture, paddy, energy water nexus, free electricity, discrete choice, Punjab, India

JEL Classification

O13, Q1, Q4, Q5, Q12, Q24, Q25, Q28, Q48, Q57

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Section 1: Introduction

One of the most serious and insidious effects of the enormous changes in Punjab agriculture over the past 60 years has been the rapid depletion and contamination of groundwater. Intensive agriculture in Punjab has led to a decline in crop diversity, depletion of natural resources, rising power use and power subsidy in agriculture, and a decline in the profitability of farming (Johl et al., 2014). These problems are considered critical for the State which has been historically considered the bread-basket of India. With only 0.03 percent of the world's geographical land, it produced about 2.6 percent of the world's rice and 2.3 percent of wheat in 2019 (Statistics of Punjab Agriculture 2020). The dominance of the rice-wheat cropping pattern tremendously increased the drawl of groundwater, which has created a situation of rapidly declining water table level over time. The average rate of decline in the last few years has been 55 cm per year. This poses a significant challenge for sustainability of water resources and potential risks for production systems and livelihoods for the future.

One of the major factors for the current groundwater crisis is related to the popular choice of high-water rice variety, commonly referred to as 'Pusa 44', despite the development of shorter-duration and low-water rice varieties such as PR 121, PR 126, and Basmati etc (Joshi et al., 2018). Given the rapid decline and overexploitation of groundwater resources, strategies are urgently needed to produce more rice with less water in the shortest possible time. It is argued that lowering the marginal benefit of the first unit of water by discouraging rice cultivation and/or increasing returns to less water-intensive crops can substantially reduce the common pool losses if coupled with marginal cost pricing of the electricity used in pumping water (Sayre and Taraz, 2019). Substitution by low-water rice variety can potentially reduce over extraction of groundwater and over consumption of free electricity (Aggarwal et al., 2009; PAU 2022). It was projected that the state could save seven billion cubic meters of groundwater and $92.14 million worth of electricity subsidy by shifting to short-duration variety in 2022 (Hindustan Times, 2022).

However a complex interplay of factors dissuades farmers from actively substituting high-water by low-water rice variety. Free electricity policy boosts the cultivation of high-water rice variety, besides encouraging free riding behaviour and low willingness to pay (WTP). The marginal cost of pumping groundwater is zero and farmers do not face the economic cost of cultivating high-water crops. Emphasis on private benefits from higher yields, coupled with free electricity and easy availability of ground water skew farmers' choice of variety in favour of high-water rice variety (Joshi et al., 2018). Further, high-water rice variety has lower production and marketing risk as compared to short duration variety. Pusa 44 rice variety is preferred due to its higher yield and resistance to lodging (Mali et al., 2001). The difference in grain yield between high-water rice variety, Pusa 44 and low-water rice short duration variety, PR 126 is estimated to be at least 5.5 quintal/hectare (Manan et al., 2018). Despite demand for basmati rice in the international market, price variability and difficulty to access price related information are important marketing problems (Grover 2012). Exploitative practices by intermediaries and lack of public procurement discourages cultivation of basmati rice (Gohain and Singh, 2018).

Further, the relative lower profitability, either due to low yield or volatile prices is perceived as a major constraint, despite the low-water rice varieties being more environment friendly. Pusa 44 variety requires more water, pesticides and other inputs (Joshi et al., 2018). It consumes 30 percent additional energy in pumping 16 percent additional volume of water as compared to the short-duration variety (Joshi et al., 2018). The expenses on fertilizers, plant protection measures, human labor use, and diesel for irrigation are considerably higher in Pusa 44 variety vis-à-vis short-duration variety (Singh et al., 2022). It is estimated that the low-water short duration rice variety saves 35 cm per hectare of groundwater and takes 35 days less than Pusa 44 rice variety (Brar, 2021). Similarly, Basmati, which is an early maturing superior rice variety consumes 38 percent less water (Brar 2021) and economizes on agri-inputs as compared to Pusa 44 variety (Singh et al., 2014). The lower input use brings down the cost of cultivation and gives more turnaround time to farmers for the timely sowing of winter crops (Singh et al., 2018). The State incurs an additional energy subsidy cost of US$ 49 million per annum on irrigating the high-water Pusa 44 variety. This cost will multiply as groundwater becomes scarcer, representing a possible burden for all times in the future.

However, there is resistance of farmers to adopt other low-water and short duration rice varieties, even though Pusa 44 requires significantly more water. The combined effect of higher returns from Pusa 44 primarily due to assured procurement, free electricity and higher yield is attributed to the low adoption rates. Farmers lack economic incentives to switch to new short-duration varieties (Joshi et al., 2018). One of the ways to induce substitution by short-duration variety is to compensate the farmer for the difference in returns. Farmers are likely to voluntarily adopt low-water crops if they are adequately compensated through financial incentives (Sidhu et al., 2020). Elimination of energy subsidies for groundwater pumping alone may not encourage farmers to switch to less water-intensive crops (Bhattarai et al., 2021). Even if the energy-subsidy is lifted, Pusa 44 farmers will not be willing to switch to a short-duration variety since the additional revenue gained from higher yield of Pusa 44 will far exceed the additional irrigation cost (Joshi et al., 2018).

There is limited evidence of the type, size and effect of various compensation possibilities in encouraging substitution of high-water rice by low-water rice variety in Punjab. Because the farmer invests time, money and inputs, understanding the ways in which farmers decide upon alternative varieties and the drivers of these decisions can be very helpful in developing policies. At times win-win conservation strategies and measures which could be beneficial both for farmers and the environment may not be successfully implemented due to the little attention given to farmers' preferences (Swinton et al., 2015). Modelling farmers' choices can help in estimating the trade-offs which can inform the design of incentive schemes to be offered to potential participants (Ruto and Garrod, 2009).

Discrete choice methodology is regarded as an appropriate research method to assess individual's willingness to adopt a certain policy instrument or innovation. Hence this paper applied a discrete choice experiment (DCE) to investigate how Punjab farmers would respond to hypothetical compensatory schemes. The discrete choice method relies upon both what respondents say they will do—also referred to as stated preference data and what they do— referred to as revealed preference data. The stated preference approach allows preferences to be elicited for options that do not exist and provides quantitative information on the strength of preferences and prediction of the likely take-up of defined options. The approach presents individuals with several hypothetical choices (often between 16 and 32). It would be hard to offer individuals such a wide range of choices in reality. The hypothetical nature of discrete choice method allows independent variables to be identified in advance, which helps in the identification of all variables of interest. Further, it helps to identify the trade-offs respondents are willing to make between attributes as well as the probability of take-up of presented options. Estimation of tradeoffs allows policymakers to estimate how much of one attribute a consumer would be willing to give up for improvement in another. Since the method accounts for preference heterogeneity, it is helpful at the policy formulation level. Consideration of heterogeneity in preferences and associated willingness to pay is important for achieving environmental objectives (Jaeck and Lifran, 2014, Jin et al., 2020).

While discrete choice methods are relatively quick and cheap survey instruments compared to other experimental methods, yet there are potential limitations of this research instrument. Stated preference methods have been critiqued because they may not predict real behaviour and choices. However, the offer of compensatory payments to farmers for switching crops applied in this paper closely resembles the real decisions being faced by them in everyday life. Another limitation concerns the external validity of the method. A complex issue is the extent to which the context and the individual experience have an impact on an individual's responses. As most DCE questionnaires present only very brief descriptions of attributes, there can be some variation in how the attributes and levels are interpreted by different respondents. It is observed that qualitative tools are helpful in understanding results of discrete choice experiments (Lagarde and Blauuw, 2009). Finally, when the attributes are currently not available (such as potential policy interventions), it is difficult to assess the extent to which respondents would easily appreciate or believe those possibilities. These challenges could be overcome in this case as Punjab farmers are being incentivized to grow low-water crops due to the ongoing groundwater crisis and are familiar with incentive schemes.

Two stated preference experiments are conducted with 859 farmers in Punjab in 2021-22 to determine the level of acceptance for compensatory payments for low-water crops and willingness to trade off free electricity for these payments, a subject that has huge policy interest, because of its environmental impact. Of particular interest is the replacement of input subsidy delivered in the form of free electricity by compensatory payments offered by way of area payment and assured prices for low-water rice varieties. The stated preferences for compensatory payments are examined and WTP values are derived. Nominal flat rates, known to have lower financial burden and easier implementation, are offered to estimate willingness to pay values. The results produce evidence of heterogeneous trade-offs between preferences for higher compensatory payments and willingness to pay fixed electricity charge.

This rest of the paper is organized as follows. Section 2 reviews the relevant literature, Section 3 discusses the discrete choice methodology, Section 4 presents results of the conditional logit and random effect probit model. Section 5 reviews the results and policy implications, and Section 6 offers conclusions.

Section 2: Review of Literature

In the field of agriculture research, discrete choice experiments have been extensively applied to determine key attributes influencing farmers' acceptance. In a study of the incentives and constraints that govern conservation decisions of small farmers in developing countries, Asrat et al. (2010) investigated Ethiopian farmers' crop variety preferences, mean willingness to pay, and the influence of household-specific and institutional factors. They found that environmental adaptability and yield stability influenced farmers' choices. Farmers were willing to forgo some extra income or yield to obtain a more stable and environmentally adaptable crop variety. In the case of Bihar in India, Ward et al. (2013) found that though farmers valued the reduction in yield variability offered by Drought Tolerant seeds but were willing to pay more for rice seeds that offered yield advantages even under normal conditions. Risk aversion and loss aversion were found to be important components of farmer utility, as these behavioural parameters not only significantly influenced choice probabilities but also affected the way farmers valued different seed attributes.

The most important influencing factor for farmers to change crops is 'economic return' of the crop and 'market factors' (Mehdi 2018). A choice experiment to examine the Influence of land tenure and property rights (LTPRs) on farmers' willingness to accept (WTA) incentives to embrace climate-smart agriculture (CSA) to combat land degradation found strong linkages between the payment vehicle, land tenure, property rights, and farmers' preferences for climate-smart agriculture in Nigeria (Shittu et al. 2018). In the case of another developing country, the attributes of crop yield, labor requirement, and cost of production were found to be significant in influencing small-scale farmers' attitudes towards conservation agriculture in Ecuador (Barrowclough and Alwang, 2018).

In a choice experiment with 202 German farmers, Breustedt et al. (2008) found that attributes such as gross margin, expected liability from cross-pollination and flexibility in returning to conventional oilseed rape significantly affected the likelihood of adoption of genetically modified oilseed rape before its commercial release. Neighboring farmers' attitudes towards genetically modified (GM) cropping and several farmer and farm characteristics were significant determinants of prospective adoption. Demand simulations suggested that adoption rates were very sensitive to profit difference between genetically modified and non-genetically modified rapeseed varieties. A stated preference experiment to explore farmers' prospective responses to the "greening" of the Common Agricultural Policy found that greening was perceived as a costly constraint in Germany (Schulz et al., 2014). Farmers' perception of risks/costs and benefits on their willingness to adopt bio energy crops in Sweden found that increased utility from a crop increases the arable land used for that crop. The size of the utility was found to depend not only on expected net income but also on the crops growing characteristics (Paulrud and Laitila, 2010).

Historically, many developing countries have used two commonly observed schemes to stimulate increases in crop production, input based subsidies which aim to reduce the input purchasing costs of farmers and output based subsides, which aim to reduce farmers' output processing costs. In the mid-1960s, the input subsidy program helped farmers during the Green Revolution in India and resulted in a positive effect on food security (Kannan, 2014). However, input based subsidies are criticised for a number of reasons: the perceived high cost, trade-offs with other development investments, opportunity cost of tying down scarce fiscal resources to unproductive uses; the political economy of scaling back subsidies which have limited effectiveness, enormous hidden and unintended long-term costs; the difficulty of targeting the poorest of the poor, encouraging over-use and ineffective use of the subsidized input thereby jeopardizing long-term sustainability; and compromising the very objectives they were originally intended to achieve. The public procurement of rice correlated with excessive groundwater use powered by subsidized electricity in water-scarce Indian states compromised long-term food security by contributing to a rapid decline in groundwater levels (Gautam, 2015). Electricity subsidies have driven the expansion of water-intensive crops, primarily rice (Badiani and Jessoe, 2012) and fertilizer subsidy resulted in overuse of fertilizers in Sri Lanka (Gautam, 2015). Input subsidies have been associated with diversion of funds which could have been used for building the necessary infrastructure for farm sector (Gulati and Sharma, 1995) and for their negative effect on public investment in Indian agriculture (Akber, 2020). Summing up, input subsidies have their limitations.

On the other hand, there is empirical evidence to show that output price policy is a more powerful tool than input price policy in influencing production decisions (Ray and Gül, 1999). Farmers tend to choose crops that can bring stable profit. Jaffe (1989) found that farmers are willing to grow crops that have a predictable market price and are easy to sell. Uncertainty of financial returns can adversely impact farmers' attitudes to plant new crops or take risks. Price risks can undermine investment and technology adoption with negative implications for farmers' welfare and food security. A study found that 30 percent of Tennessee farmers were willing to grow switchgrass if it were profitable (Jensen et al., 2007). Economic factors, particularly the availability of an established market and an assured high return per acre were identified as the most important factors for growing biomass in Central Florida (Rahmani et al., 1996). The selling price of biomass was perceived to be a major barrier discouraging landowners from producing biomass in the Great Lakes region (Campbell, 1989).

Price support is a prominent tool used by countries all over the world to help farmers hedge against income losses and to smoothen out price fluctuations (Abokyi et al., 2020). A historical review of cross-country experience shows that Governments in Asia have used grain price stabilization as a major policy instrument for boosting food grain production (Cummings et al., 2006; Fang, 2010). The primary means of intervention are deficiency payments for cotton and floor prices for grains and oilseeds in Turkey (Demirdogen et al., 2021). The European Union's Common Agricultural Policy uses area payments and minimum guaranteed prices to support arable crops (Sckokai and Moro, 2006).

It has been empirically established that farmers are most influenced by economic incentives. In Western Europe, farmers have reacted quickly to changes in price incentives and within the constraints of topography, soils, rainfall , access to markets, etc., have rapidly adopted crops and practices (Boardman et al., 2003). The United States offers farmers cash payments as incentives to adopt conservation practices through initiatives such as the Conservation Reserve Program (Cox 2006). Incentive-based measures have been used to decrease rates of water extraction. Countries have implemented administrative, legislative, or management controls, including economic incentives to reduce the demand for water (Molle 2003). Incentives have been used to promote sustainable resource use (Repetto 1987, Bopp et al., 2019), encourage adoption of better agriculture practices (Wade et al., 2015, Purola and Lehtonen, 2022) and foster the adoption of sustainable agriculture practices by farmers (Bopp et al., 2019).

Section 3: Discrete choice experiment approach

This study examines the effectiveness of incentives on the adoption intensity of low water rice variety among paddy growing farmers in Punjab. We assess the response of farmers to direct payments and price support in inducing substitution of high-water by low-water rice variety in Punjab. The argument is that the reallocation of funds from subsidy on electricity to compensatory payments on farm produce could incentivize farmers to shift to low-water rice variety. This move could curtail electricity subsidies and ease pressure on groundwater. Research and analysis is necessary before proper compensatory payments can be designed to influence farmers' choices.

In the economics literature, the choice experiment is an established method for conducting economic valuation of alternatives before policy change. Discrete choice method presents the respondent with alternatives defined by attributes and levels. The method helps to understand how respondents choose from different alternatives and allows evaluation of individual preferences for various attributes and the trade-offs they are willing to make between these attributes. In this study, farmers' preferences for a hypothetical compensatory payment scheme for substitution by low-water rice variety is estimated using a stated preference approach to unravel its potential success in driving a change from the delivery of electricity subsidy to delivery of incentive payments for adoption of crops with low-water requirements.

The aim is to investigate whether compensatory payments can influence willingness to substitute high-water intensive rice variety with low-water intensive variety and willingness to pay for electricity. To our knowledge, this is a novel exercise. This study differs from the choice literature as stated preferences are examined by offering two types of compensatory payments for substitution by low water rice varieties and the trade-offs between compensatory payments and payment for electricity are also investigated. Experiment A examines farmers' preferences for substitution by short-duration rice variety with the offer of area-based payment per acre. Experiment B studies farmers' preferences for substitution by basmati with the offer of minimum assured price per quintal of rice produce.

Description of attributes

In reality, rice variety choices of farmers and willingness to pay electricity charge are interconnected. Accordingly the purpose of this study is to examine how farmers rate scenarios that include both aspects and how they trade off these two attributes against each other. Since the scope of the experiment was to examine farmers' preferences for low-water rice variety by offering area-based payment and minimum guaranteed price, the number of attributes were restricted to those most likely to influence the substitution pattern and willingness to pay fixed electricity charge. The choice sets vary two attributes with three levels: 1) Compensatory payment, defined by area-based payment per unit of land for substituting short duration rice variety and minimum support price for substitution by basmati rice variety; 2) Price of electricity, defined by fixed monthly charge or connected load-based charge. Attributes and levels are presented in Table 1 and an example of a choice set for each of the two experiments is shown in Figure 1 and Figure 2.

It was felt that increasing the burden of the choice task, in terms of the time required or the number of choices to be presented, could reduce the response rate for the questionnaire. A large number of choices or attribute levels was expected to lead to respondent fatigue bias or loss of interest in the task. Therefore, it was decided that no more than three levels for each attribute should be included. A pilot study was undertaken with farmers in the Malwa region to assess the validity of the questionnaire and to determine whether the selected attributes and levels were capable of being traded-off against one another within a stated preference framework. The levels were calibrated and fine-tuned on the basis of the feedback received during the pre-tests.

a. Compensatory payment for substitution

Area-based monetary payment per unit of land is offered for substitution by short duration rice variety. The yield difference between short duration and long-duration variety is comparatively lower and can be compensated by offering payment per unit of land. On the other hand, minimum assured price per quintal is offered for substitution by basmati rice variety where the yield difference is larger. The three levels of area-based payment offered to the farmers were – Rs. 4000 per acre, Rs. 4200 per acre, and Rs. 4500 per acre. The three levels of minimum assured price included in the study were Rs. 3000 per quintal, Rs. 3200 per quintal, and Rs. 3500 per quintal.

The attribute of compensatory payment was drawn from the experience of the use of cash incentives by governments to induce farmers to choose one agriculture practice over another. The neighboring state of Haryana disbursed a cash incentive of Rs. 4000 per acre to farmers to adopt direct seeding of rice as opposed to transplanting seedlings from the nursery (The Tribune 2022a), Rs. 7000 per acre for growing non-paddy crops (Krishijagran 2020) and Rs. 4000 per acre for growing pulses and oilseeds (The Tribune 2022b). Under a project funded by the National Bank for Agriculture and Rural Development, farmers in Punjab adopting maize were offered Rs. 23500 per hectare (Indian Express 2021).

The first level of Rs. 4000 per acre was determined considering an average yield difference of two quintals per acre between long-duration and short-duration rice variety. Area-based payment was increased by five percent and twelve percent for the second and third level of Rs. 4200 per acre and Rs. 4500 per acre. The first level of minimum assured price offered was Rs. 3000 per quintal to nearly equalize the return from basmati with return from long duration rice variety. The first level was increased by six percent and sixteen percent to arrive at the next two levels of Rs. 3200 per quintal and Rs. 3500 per quintal after rounding off. The status quo alternative was included in the choice set as some farmers were expected to continue with the existing variety because of subjective concerns about perceived yield differences and risks associated with choosing low-water rice variety.

b: Price of electricity

The price attribute includes uniform monthly rate and fixed charge on sanctioned load basis. The three levels are (1) Zero electricity charge except nominal enrollment fee of Rs. 100 ($1.25) per year, (2) Uniform monthly electricity charge of Rs. 100 ($1.25) per month and, (3) Fixed charge on sanctioned load of Rs. 10($0.12)/HP/month.

Indian Distribution Utilities levy flat rates, where payment is linked to the rating of water pump or variable charge on the basis of meter reading. Flat rates have lower administrative costs and more equitable distributional effects but provide no incentive for water conservation. Conversely, metered tariffs have the potential to encourage judicious consumption, but are expensive to manage and disadvantageous to low-income farmers who often buy water from wealthier groundwater well owners (Sidhu et al., 2020). Flat electricity charge was selected as this does not depend on meter installation. A metered rate was avoided as there is strong opposition to metering among Punjab farmers. One of the main causes of opposition to electricity payment is metering (Mukherji and Das, 2014). Further, farmers are familiar with monthly rates as these are being paid in some Indian States.

In the case of Punjab, farmers are familiar with fixed charge on sanctioned load basis, having paid such charges prior to introduction of free electricity policy in 1997. Fixed charge on sanctioned load has been levied in the past, for instance, Rs. 20/BHP/month in 1990 (PSPCL Commercial circular 41/90), Rs. 25/BHP/month in 1992 (Commercial circular 36/92), Rs. 50/BHP/month in 1993 (Commercial circular 54/93), Rs. 65/BHP/month in 1994 (Commercial circular 25/10/94) and Rs. 50/BHP/month in 1996 (Commercial circular 10/7/96). A charge of Rs. 10/BHP/month was included as the third level as this would be similar to what farmers would have been previously paying. A very high flat rate was not included to elicit genuine willingness to pay and not discourage payment behaviour. A very high electricity charge would not be affordable to marginal and small farmers. Hence a nominal uniform charge of Rs. 100 per month was included.

In terms of cost recovery, the nominal fixed charge is not profitable for the distribution utility, but these face less resistance. For instance, the rate of power supply applicable to agriculture consumers as per Tariff Order 2022-23 was Rs. 5.66/kWh. At an average consumption of 7000 kWh, the expected annual revenue would be Rs. 39620 per year. The proposed monthly tariff of Rs. 100/month would generate annual revenue of Rs. 1200 per pump. The advantage of using load-based tariff of Rs. 10/HP/Month is the feasibility of evaluating willingness to pay with difference in load capacity. The payment burden would be Rs. 1200 per year for 10 HP motor, Rs. 2400 for 20 HP pump and so on. This charge would impose higher burden on consumers with higher capacity motors and discourage farmers from using higher capacity motors in the long run.

Table 1: Attributes and Levels for Experiments A and B

	Experiment A	Experiment B
Incentive for low- water rice	Assured Procurement of PR-121/126 at MSP + Rs. 4000 per acre	Assured minimum price of Rs. 3000 per quintal for Basmati
	Assured Procurement of PR-121/126 at MSP + Rs. 4200 per acre	Assured minimum price of Rs. 3200 per quintal for Basmati
	Assured Procurement of PR-121/126 at MSP + Rs. 4500 per acre	Assured minimum price of Rs. 3500 per quintal for Basmati
Price of electricity	Zero electricity charge with nominal annual enrollment fee	Zero electricity charge with nominal annual enrollment fee
	Payment of Rs. 100/month	Payment of Rs. 100/month
	Payment of Rs. 10/HP/month	Payment of Rs. 10/HP/month

Figure 1: Example Choice Set for Experiment A

Attribute	**Intervention versus status quo**
Area based payment for shift to short duration variety	Rs. 4200 per acre + MSP  **Rs. 4200/acre + MSP**
Price of electricity	Monthly charge for electricity **Pay Monthly** Rs. 100/month
Would you take up this intervention? Please tick	***Yes*** ☐ ***No*** ☐

Figure 2: Example Choice set for Experiment B

Attribute	**Intervention versus status quo**
Minimum assured price for shift to Basmati	Rs. 3500 per quintal  **Rs. 3500/qtl**
Price of electricity	Load based charge for electricity  Rs. 10/HP/month
Would you take up this intervention? Please tick	***Yes*** ☐ ***No*** ☐

A fractional factorial design was generated to produce nine 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 (Ryan et al., 2012). Nine choice cards were presented to each farmer with a binary choice – willing to substitute low-water rice for high-water rice variety and to pay for electricity. While a discrete choice framework is usually used for stated preference choice experiments ("do you prefer A, B, or neither"), a binary choice framework ("would you accept the hypothetical compensatory payment incentive or not?") was adopted as it better reflects the nature of the problem. The analysis used 859 questionnaires completed by farmers, yielding 7731 observations. The main socio-economic variables of interest were age, education, land acres owned, sanctioned load, and the number of tube wells owned.

Model specification

A binary logit model was used to determine the probability that a farmer would choose to adopt the short duration and basmati rice variety. Following Louviere et al. (2000), a random utility model is defined as:

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

$$i = 1, \ldots . I \text{ } and \text{ } n = 1, \ldots \ldots N,$$

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:

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

$$= P_r\left[V_{in} + \varepsilon_{in} \geq V_{jn} + \epsilon_{jn}\right] \tag{2}$$

$$= P_r\left[\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}\right]$$

For all $i, j \in C$

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

Assuming the random errors in Equation (1) are independently and identically distributed across the *I* alternatives *(i=1………I)* and *N* individuals (*n=1……..N)* as a type I extreme value distribution, that is, $\varepsilon_n = \varepsilon_{jn} - \varepsilon_{in}$ in Equation (2) is logistically distributed, the probability of farmer *n* choosing alternative *i* is given by:

$$Pni = \frac{exp\mu(Vin)}{\sum_{j=1}^{n}(exp(Vjn)} \quad (3)$$

where $\mu > 0$ is the scale parameter, assumed equal to one, because it is unidentifiable within any particular dataset and cannot be distinguished from the overall scale of the estimated coefficients of the linear parameters, βs.

According to Louviere et al., (2000), in a binary logit model, the probability of adoption can be expressed as:

$$P(yes|yes,no) = exp\left(V_{yes}\right)/\left[exp\left(V_{yes}\right) + exp(V_{no})\right] \quad (4)$$

where the Vs are the systematic utility components. Following Louviere (2000), the value of V_{no} can be set to zero with no loss of generality, satisfying the identification restriction in the binary logit model. Thus, Equation (4) can be rewritten as:

$$P(yes|yes,no) = exp\left(V_{yes}\right)/\left[exp\left(V_{yes}\right) + 1\right] \quad (5)$$

The odds of responding 'yes' relative to 'no' would be:

$$\frac{P(yes|yes,no)}{P(no|yes,no)} = \frac{exp(Vyes)/exp(Vyes)+1}{exp(Vno)/exp(Vyes)+1} = \frac{exp(Vyes)}{exp(Vno)} \quad (6)$$

But *exp* (V_{no}) = 1, hence the odds of responding yes relative to no involve influences only on 'yes'. Taking the natural logarithms of both sides,

$$log\ e\frac{P(yes|yes,no)}{P(no|yes,no)} = Vyes \quad (7)$$

V_{yes} can be specified as linear in the parameters' expression such that:

$$Vyes = \sum_{K} \beta_k X_k + \sum_{m} \alpha_m Z_m \quad (8)$$

where β_k is a vector of taste weights associated with K attribute vectors, X_k and α_m is a vector of effects associated with *M* individual characteristics interacted with either the 'yes' intercept or elements of the *X* vector, Z_m.

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:

$$Adoption_{in} = \beta_0 + \beta_1 \text{xPayment1}_{in} + \beta_2 \text{xPayment2}_{in} + \beta_3 \text{xPayment3}_{in} + \beta_4 \text{xPrice1}_{in} + \beta_5 \text{xPrice2}_{in} + \varepsilon_{in} \quad (9)$$

where $Adoption_{in}$ is a notional replacement for V_{in} identifying those respondent farmers who preferred adoption of new variety change; β_1 to β_5 are the parameters to be estimated, where larger values of β indicate greater utility, and thus more preferred attributes; β_0 is a constant reflecting respondents' preference for accepting incentive for changing rice variety relative to no change in crop variety; and ε_{in} is the random error term. The explanatory variables include dummies for the payment levels and the price of electricity. Following standard econometric convention, L-1 attribute levels were required for model estimation, which means that the Lth level attributes were omitted in the model.

After the parameters have been estimated, the willingness to pay is given by the following formula:

$$Willingness\ to\ pay = \frac{\beta_{Payment}}{\beta_{Price}} \quad (10)$$

The probability that a person will say 'yes' to a scenario i in choice situation t is:

$$Probability(Y|Y,N;X) = probability\left(U_i^{yes}\right) \geq \left(U_i^{no}\right)$$

$$= P\left(exp^{Vyes/} \Sigma\, exp\left(^{Vyesii+Vnoi}\right)\right)$$

$$= \frac{1}{1+ \mathrm{e}^{(-V_{int})}} \quad (11)$$

where V_{int} is systematic utility and is assumed linear in parameters and a function of matrix of attributes and their levels pertaining to the adoption of short duration crop variety (Ryan et al., 2003). Marginal effects were used to measure the change in probability of adopting the short duration variety or basmati variety due to a given change in the explanatory variable.

Estimation strategy

A conditional logit model and random effects probit model was applied to estimate respondent preferences for attributes and levels. Pseudo R^2, AIC and BIC give slight dominance to conditional logit. Traditionally the choice is modeled using conditional logit formulation, in which the error terms are assumed to be independently and identically distributed according to Gumbel distribution. The conditional logit model is criticized for its restrictive assumptions. The choice is independent of irrelevant alternatives (IIA). As a result, the conditional logit formulation is not capable of capturing unobserved heterogeneity (Siyaranamual et al., 2020). However recent models have tried to increase the behavioural realism of choice models. A random effects specification can be used to take account of the multiple observations obtained from each respondent and relaxes the IIA assumption (Ryan and Hughes, 1997, Ryan et al., 2003).

When the respondent faces a binary choice (e.g. would you choose alternative A: yes/no), the probit model can be applied. A probit specification is assumed where disturbances ε_{in} are distributed according to standard normal distribution with zero mean and constant variance σ^2. The simple probit model assumes that the error term is independent ε across observations. Assuming a linear utility function V(.), the utility to be estimated for moving from high-water to low-water rice variety can be given as

$$\Delta V = \alpha_{1SD} x Payment + \alpha_{2SD} x Price + \theta \tag{12}$$

where ΔV is the change in utility in moving from high-water to low-water rice variety, 'Payment' is the difference in the level of compensatory payment and 'Price' is the difference in the price of electricity. α_1 and α_2 are the parameters of the model to be estimated. Θ is the unobservable error term for the model. The ratio of any pair of these shows the marginal rate of substitution; α_j / α_2 (j = 1, 2, 3), which is an estimate of the willingness to pay for levels of individual attributes. ΔV is the observed difference between the utility from high-water rice variety versus that of low-water rice variety; it is observed for each discrete choice whether the individual chooses high-water or low-water rice variety. ΔV is a binary variable, taking the value of 0 if the individual chooses high-water rice variety and 1 if the individual chooses low-water variety.

Random effects probit model in addition to conditional logit model was used to estimate the model. Each respondent was shown nine choice cards, each choice was treated as a separate observation and multiple observations were obtained from each respondent in the experiment. The stated preference experiment gave 7731 choice observations for substitution by short duration rice and 7731 observations for substitution by basmati rice variety. The coefficients represent the utility corresponding to each level of attribute used in the choice experiment and can be interpreted as the change in utility in substituting long-duration variety by short-duration and basmati rice variety.

Section 4: Empirical Results

Looking at the results of random effects probit and conditional logit model (in Table 2), the signs of the coefficient for attribute main effects are as expected, suggesting that the model is consistent with a-prior expectation. All the attributes are significant and influence the probability of substitution of high-water variety by both low-water rice varieties.

Higher compensatory payment, in the form of Area based payment for short duration rice variety in Experiment A and Minimum Assured Price for Basmati rice variety in Experiment B elicits stronger substitution preferences. The status quo was chosen at the lowest level of compensatory payment in both experiments. There are negative preferences for payment of electricity compared to no electricity charge. The negative price coefficients are lower for fixed uniform monthly electricity charge. Significant standard deviations indicate heterogeneity among farmers for compensatory payment and electricity charge. The pseudo R^2 of the model is 0.25, which is a good fit, and the overall model is highly significant. These results provide evidence of the theoretical validity of the model. The estimate of ρ is statistically significant, suggesting that this is the correct estimation technique. The statistical significance of Rho (Rho = 0.37 and 0.33, P<0.000) implies there is significant unobserved correlation over multiple responses from each individual, suggesting that a random effects specification is appropriate. The model is statistically significant (Prob>chi2 = 0.000).

Table 2: Estimation Results

Attribute	Coef.	Std. Err.	Coef.	Std. Err.
Experiment A	Conditional logit		Random effects probit	
Payment_4200	2.2522***	0.0835	1.3129***	.04667
Payment_4500	2.4870***	0.0852	1.4804***	.04786
Price_Payment_100	-0.022***	0.0008	-.01328***	.00047
Price_Payment_10_HP	-0.2776***	0.0090	-.1566***	.00475
Log likelihood	-2080.5028		-3908.2351	
Pseudo r-squared	0.37		0.25	
Cons			-.1413***	.0459
lnsig2u			-.5001	.0775
sigma_u			.7787	.0302
Rho			.37751	.0182
Experiment B				
AssurePric_3200	1.2895***	0.0752	.7607***	.0437
AssurePric_3500	2.3555***	0.0819	1.4101***	.0466
Price_AssurePric_100	-0.0180***	0.0007	-.0102***	.0004
Price_AssurePric_10_HP	-0.3174***	0.0090	-.1842***	.0048
Log likelihood	-2161.5885		-3949.4358	
Pseudo r-squared	0.37		0.25	
Const			.1888***	.0443
lnsig2u			-.6824	.0817
sigma_u			.7108	.0290
Rho			.3357	.0182
No of observations	7731		7731	

*******P<0.05*

In Table 2, P*ayment_4200, Payment_4500, Price_Payment_100* and *Price_Payment_10_HP* represent estimated coefficients for area-based payment attribute of Rs. 4200 per acre, and Rs. 4500 per acre for substitution by short duration rice variety attribute and electricity price attribute of Rs. 100 per month and Rs. 10/HP/month in Experiment A respectively. *AssurePric_3200, AssurePric_3500, Price_AssurePric_100, Price_AssurePric_10_HP represent* coefficients for minimum assured price attribute of Rs. 3200 per quintal and Rs. 3500 per quintal for substitution by basmati rice variety, and electricity price attribute of Rs. 100/month and Rs. 10/HP/month for Experiment B respectively.

Willingness to pay/willingness to accept: WTP/WTA is the marginal rate of substitution between an attribute and the price attribute. It is estimated as the ratio of the value of the coefficient of interest, the compensatory payment, to the negative of the price of electricity coefficient. This method is repeated to estimate the WTPs for substitution by both the low-water rice varieties. Delta method confidence intervals are calculated using the nlcom command in STATA (Hole 2007). Table 3 below shows the WTP/WTA estimates, and their corresponding 95% intervals. The results indicate that respondents' willingness to pay increases with higher compensatory payment.

The WTP/WTA is Rs. 99.46 ($1.24) per month and Rs. 8.38($0.10)/HP/month for area-based payment of Rs. 4200 per acre and Rs. 112 ($1.40) per month and Rs. 9.45($0.11)/HP/month for Rs. 4500 per acre for substitution by short-duration rice variety. The WTP/WTA is Rs. 74.4 ($0.93) per month and Rs. 4.12($0.05)/HP/month for minimum assured price of Rs. 3200/quinital and Rs. 137 ($1.73) per month and Rs. 7.65($0.09)/HP/month for Rs. 3500/q for substitution by basmati rice variety. The similarity of results under logit and probit models suggests a high level of convergent validity between the two models. The WTP/WTA valuations are higher for fixed monthly electricity charge with minimum assured price for basmati and higher for load-based electricity charge with area-based payment for substitution by short-duration rice variety. This result shows that the government may consider imposing load-based electricity charge by offering guaranteed minimum purchase price of basmati rice variety.

Table 3: Willingness to pay values

Attribute	Conditional logit	Random effects probit	Conditional logit	Random effects probit
	WTP on monthly basis		*WTP on load basis*	
Payment_4200	99.35*** (4.41)	99.46*** (4.29)	8.111*** (0.321)	8.38*** (0.333)
Payment_4500	109.71*** (4.68)	112.14*** (4.54)	8.957 (0.335)	9.45*** (0.346)
AssurePric_3200	71.48*** (4.79)	74.43*** (4.97)	4.061*** (0.234)	4.12*** (0.24)
AssurePric_3500	130.58*** (6.49)	137.96*** (6.69)	7.41*** (0.264)	7.65*** (0.264)

Standard deviation in bracket
****P<0.05*

Change in probability: By differentiating the probability function with respect to changes in the level of the attribute, the effectiveness of different policies can be forecasted. A useful output when using discrete choice experiments is to identify how the probability of choosing a certain offer changes as the levels of attributes are changed (Ryan et al., 2012). Table 4 presents the impact of the policies. While compensatory payment is a powerful instrument to encourage shift to low-water crops, this instrument is less effective for encouraging adoption of short-duration rice as compared to basmati rice. That is, raising the area-based payment of Rs. 4200 per acre to Rs. 4500 per acre increases the probability of substitution by short-duration rice by 8.3 percentage points. The probability of substitution by basmati increases by 31 percentage points with the increase in minimum assured price from Rs. 3200/quintal to Rs. 3500/quintal. The probability of acceptance to pay uniform monthly electricity charge is significantly higher than for load-based electricity charge.

Table 4: Change in probability

Attribute	Coefficient	Std. Err.	Coefficient	Std. Err.
	Conditional logit		Random effects probit	
Payment_4500	0.1168***	0.034	0.0835***	0.020
Price_Payment_100	0.1268***	0.004	0.0715***	0.002
AssurePric_3500	0.4876***	0.027	0.3137***	0.019
Price_AssurePric_100	0.1486***	0.004	0.0867***	0.002

******P<0.05*

Probability of take up: 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 (Ryan et al., 2012). The probability of uptake is simulated for the different attribute levels. Adoption is compared for improved attributes (as a result, for example, of reform efforts) with respect to the base line attribute. The uptake probability is predicted to be 67 percent for area-based payment of Rs. 4200 per acre and 71 percent for area-based payment of Rs. 4500 per acre in Table 8. Similarly, the probability of uptake for minimum assured price of Rs. 3200 per quintal is 61 percent and 74 percent for minimum assured price of Rs. 3500 per quintal.

Table 5: Predicted probabilities

Attribute	Coef. (Std. Err.)
	Probit
Payment_4200	0.6777***
	(0.0104)
Payment_4500	0.7134***
	(0.0103)
AssurePric_3200	0.6189***
	(0.0104)
AssurePric_3500	0.7480***
	(0.0981)

****$p < 0.05$*

Comparison of coefficients between the regions: The area of Punjab is divided into three sub-regions – Malwa, Majha, and Doaba. Majha comprises of districts of Amritsar, Pathankot, Gurdaspur, and Tarn Taran. Historically, it derives its name from being the central region of the older Greater Punjab which extended from Jamuna to Indus. This 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. It remains one of the largest per capita producers of wheat in the world to this day. Malwa is the region to the south of river Sutlej and makes up a large part of the state comprising more than 11 districts. A comparison of preference behaviour between farmers in the three regions of Majha, Malwa and Doaba in Table 6 shows that farmers in the Malwa region are most likely to accept area-based payment for substituting by short-duration rice variety. Farmers in the Doaba region value higher area-based payment for shifting to short-duration rice variety. Farmers in the Majha region are likely to substitute high-water rice variety by basmati variety with the offer of minimum assured price. Farmers in the Doaba region and in Majha region have lower negative preferences for willingness to pay for electricity with offer of area-based payment for short duration rice and offer of minimum assured price for basmati rice variety respectively.

Table 6: Estimation results - region-wise

Attribute	Malwa	Majha	Doaba
Experiment A			
Payment_4200	2.2557***	2.2447***	2.2471***
Logit model	(0.10)	(0.18)	(0.21)
Payment_4200	1.3151***	1.3076***	1.3103***
Probit model	(0.05)	(0.10)	(0.11)
Payment_4500	2.4867***	2.4792***	2.4982***
Logit model	(0.10)	(0.18)	(0.21)
Payment_4500	1.4804***	1.4749***	1.4861***
Probit model	(0.59)	(0.10)	(0.12)
Price_Payment_100	-.02268***	-.02284***	-.0223***
Logit model	(0.001)	(0.001)	(0.002)
Price_Payment_100	-0.0132***	-0.0132***	-0.0130***
Probit model	(0.005)	(0.001)	(0.001)
Price_Payment_10_HP	-.2774***	-.2803***	-.2747***
Logit model	(0.01)	(0.02)	(0.02)
Price_Payment_10_HP	-0.1564***	-0.1581***	-0.1552***
Probit model	(0.005)	(0.010)	(0.012)
Experiment B			
AssurePric_3200	1.2811***	1.3614***	1.2289***
Logit model	(0.09)	(0.167)	(0.19)
AssurePric_3200	0.7558***	0.8048***	0.7235***
Probit model	(0.05)	(0.09)	(0.11)
AssurePric_3500	2.3468***	2.4228***	2.3034***
Logit model	(0.10)	(0.183)	(0.20)
AssurePric_3500	1.4053***	1.4495***	1.3794***
Probit model	(0.05)	(0.10)	(0.11)
Price_AssurePric_100	-.0180***	-.01798***	-.01803***
Logit model	(0.0009)	(0.001)	(0.002)
Price_AssurePric_100	-0.0102***	-0.0102***	-0.0102***
Probit model	(0.0005)	(0.0009)	(0.001)
Price_AssurePric_10_HP	-.3175***	-.31533***	-.3201***
Logit model	(0.011)	(0.0200)	(0.02)
Price_AssurePric_10_HP	-1.8422***	-1.8315***	-1.8576***
Probit model	(0.006)	(0.01)	(0.01)

****P<0.05*

Non-linear effects through interaction: Segmentation analysis is conducted to determine the effect of socio-economic and demographic characteristics of farmers on their preferences for different attribute levels. In order to allow for such nonrandom variation in preferences, interaction terms are estimated for the attribute levels with education qualification, land size, load capacity, and tube well ownership. Farmers are classified into five groups on the basis of land size (below 1 hectare, 1-2 hectares, 2-4 hectares, 4-10 hectares and above 10 hectares). Similarly, load ownership is grouped into three categories – low (below 15 HP), medium (15-50 HP) and high (above 50 HP). Farmers are grouped into single tube well owning and multiple tube well owning categories. Education qualification is classified into three sub-groups levels – up to matriculate, up to graduate and beyond graduate. As middle aged farmers between 31-50 years constituted almost 50 percent of the respondent farmers possessing similar experience, experience as a characteristic of farmers was not considered for segmentation analysis. The interaction of the attribute variables with the socio-economic and demographic variables gave both significant and non-significant results. Equation 13 illustrates the specification of some of the interaction terms.

$$\begin{aligned}\Delta V = {} & \alpha 3 \; x \; Areapayment4200\#Marginal + \alpha 4 \; x \; Areapayment4200\#Small + \\ & \alpha 5 \; x \; Areapayment4200\#Semimedium + \alpha 6 \; x \; Areapayment4200\#Medium + \\ & \alpha 7 \; x \; Areapayment4200\#Large + \alpha 8 \; x \; Areapayment4200\#Lowload + \\ & \alpha 9 \; x \; Areapayment4200\#Mediumload + \alpha 10 \; x \; Areapayment4200\#Highload \\ & + \\ & \alpha 11 \; x \; Areapayment4200\#Singlewell + \alpha 12 x \\ & Areapayment4200\#Multiplewell + \alpha 13 \; x \; Areapayment4200\#School + \alpha 14 \; x \\ & Areapayment4200\#College + \alpha 125 \; x \; Areapayment4200\#University\end{aligned} \tag{13}$$

The results of the interaction terms are shown in Table 8 in the Appendix. Matriculate farmers are significantly more likely to prefer to pay monthly electricity charge with area-based payment, unlike farmers holding education qualifications higher than graduate degree. Marginal and medium farmers significantly prefer to pay load-based electricity charge with area-based payment. Farmers with high load have significantly negative preferences for paying electricity charge on monthly and load-basis with area-based payment; farmers with low and medium load are more likely to pay electricity charge, although the result is not significant. Multiple tube well owning farmers significantly prefer to pay load-based tariff with area-based payment.

The interaction terms for substitution by basmati rice show that farmers with low load, high load and single tube wells do not significantly prefer minimum assured price of Rs. 3500/quintal. Farmers with low and medium load, multiple tube wells and medium landholdings are likely to prefer paying load-based charge with minimum assured price, although the result is not significant. Matriculate farmers are significantly more likely to pay load-based electricity charge. Generally, education has a positive effect on willingness to pay for electricity with offer of minimum assured price for substitution by basmati rice variety.

Section 5: Discussion

Using data from two stated preference experiments with Punjab farmers, this paper finds empirical evidence of strong preference for output price support among Punjab farmers for substitution of high-water-rice by low-water rice varieties. Positive and significant preferences are observed for the attribute of area-based payment for substitution by short-duration variety and attribute of minimum assured price for substitution by basmati rice variety. Furthermore, farmers are more likely to opt for the status-quo option or continue with the high-water rice variety at the lowest level of area-based payment and minimum assured price accompanied with a payment for electricity attribute.

The acceptance rate for the different bundles of compensatory payment and electricity charge varies across farmers. As expected, ceteris paribus the acceptance rate increases for higher compensatory payment and lower burden of electricity charge. It is found that 77 percent of the farmers prefer statistically significant compensation of Rs. 4200 per acre for substitution by short-duration rice and 74 percent prefer minimum assured price of Rs. 3200/q for substitution by basmati rice. The coefficients increase significantly with higher compensatory payment level, suggesting that farmers are sensitive to the magnitude of the payment for substitution. The standard deviations show that the respondents value certain aspects to varying degrees. Socioeconomic characteristics are found to be significant determinants governing farmers' preferences.

The results illustrate that compensatory payment in the form of area-based payment and minimum assured price for substitution by low-water rice can be combined with electricity charge on a monthly or load-basis, depending on farmers' preferences. Significant heterogeneity is found in the valuation for compensatory payment combined with electricity charge. There is higher probability of acceptance for fixed monthly charge on electricity. The offer of area-based payment of Rs. 4200 per acre and monthly electricity charge of Rs. 100 is acceptable to 66 percent of the farmers. In respect of load-based charge on electricity, higher area-based payment of Rs. 4500 per acre can incentivize willingness to pay with around 55 percent of the farmers willing to accept such a scheme. Hence, there is evidence that higher area-based payments can incentivize farmers to pay electricity bills. In the case of substitution by basmati rice variety, the acceptance rate is 58 percent for minimum assured price of Rs. 3200/q and fixed monthly electricity charge of Rs. 100/month. At the same level of fixed monthly charge on electricity, higher minimum assured price of Rs. 3500/q has 66 percent acceptance among farmers. Minimum assured price combined with load-based electricity charge significantly influenced the likelihood of acceptance of electricity payment by 58 percent of the farmers. Therefore, there is evidence that farmers are willing to forgo some free electricity to obtain compensatory payments for substitution by low-water rice variety. The negative coefficients for load-based electricity charge are higher than for monthly electricity charge. This shows farmers' relative preference for uniform monthly electricity charge than load-based charge.

The main specification of the model allowed the estimation of the amount farmers are willing to pay for electricity with compensatory payment for substitution by low-water rice variety. There is evidence of trade-off between free electricity and compensatory payment for substitution by low-water rice variety. It is found that farmers are willing to sacrifice Rs. 99/month and Rs. 112/month for area-based payment of Rs. 4200 per acre and Rs. 4500 per acre for substitution by short duration rice variety respectively. Farmers are willing to sacrifice Rs. 74/month for Rs. 3200/q and Rs. 137/month for minimum assured price of Rs. 3500/q for substitution by basmati rice. These findings can shed light on the trade-offs farmers are willing to make for assured output price support for substitution by low-water rice variety. Policymakers could use this information to encourage payment behaviour while designing compensation schemes.

The interviews show a relative preference for minimum assured price for substitution by basmati variety as compared to area-based payment for short-duration rice variety. Furthermore, there is higher preference for 1509 variety basmati rice, than 1121 variety which has comparatively lower yield. A practical difficulty is the perceived risk of farmers falsely presenting the high-water rice variety, Pusa 44 to claim compensatory payment entitled for short-duration rice, as harvested produce of the long and short-duration variety looks quite similar. This could invalidate the objective of the incentivization scheme to promote substitution by short-duration varieties. However, this practical difficulty could be addressed with the help of technological solutions.

This study provides empirical evidence that farmers are likely to substitute by low-water rice variety with compensatory payment. The incentive-induced diversification in favor of low-water rice varieties can be achieved by almost revenue-neutral financing of the scheme from the subsidy savings resulting from substitution by low-water and low energy-intensive rice varieties. Currently, the government is spending $747.2 million (2018-19) on providing free electricity for agriculture pumps. Repackaging the input subsidy as output price support can contribute significantly to financing the compensatory payment program to induce substitution by low-water rice varieties. For instance, the short-duration variety, PR 126 takes 35 fewer days to grow, which can result in reduced pumping of groundwater and reduced electricity consumption. This subsidy saving can finance the compensatory payment to induce substitution by low-water rice variety which further leads to lesser water requirement in addition to reduced energy requirement.

A simple cost-benefit analysis is presented in Table 7 to understand the implications of substitution by short-duration rice variety. The analysis is conducted for ten percent of the acreage under rice crop, say about 778382 acres. This would be equivalent to diverting 40 percent of the area under high-water rice to low-water rice variety. The saving is estimated on the basis of two criteria, first reduced pumping hours and second reduced groundwater draft. The cost of disbursing area-based payment of Rs. 4200 per acre to induce substitution by PR 126 (short duration rice variety) would be $41.04 million. The savings from electricity subsidy would be $55.5 million due to reduced daily hours of pumping and $14 million on account of reduced demand for groundwater. Electricity subsidy savings are calculated on the basis of two criteria – the daily cost of pumping estimated by the utility and optimal irrigation water requirement for different crops worked out by the Punjab Agriculture University. As there is likelihood of farmers overusing water, hence the subsidy savings from reduced cost of pumping may be more realistic. The reduction in maturing days would lead to substantial groundwater savings of 1.089 billion cubic meters and carbon emission saving of 156389.454 tons/MWh. In addition, the State Electricity Distribution Utility could earn revenue of $2.01 million from the levy of fixed monthly electricity charge on agriculture pumps.

Table 7: Cost-benefit analysis

For the Government		
Area under Pusa 44	acres	1981785
10% area under rice diverted to PR 126	acres	778382
Water table depth	Feet	100
Pumpset capacity	BHP	10
Average area irrigated reduced by 10 HP in one day	acres	1
Saving due to shift from Pusa 44 to PR 126	days	35
Cost of running for 4 hours daily*	$	61.16
Estimated saving of electricity cost for 35 days per acre	$	71.36
Saving in electricity cost for 10% area diverted to PR126	$	55.5 million
For the Environment		
Groundwater savings		
Groundwater savings on shift from Pusa 44 to PR 126 **	cm	35
Per acre groundwater savings	cm	1400
Total groundwater savings on 10% area diverted to PR 126	billion m3	1.0897348
Carbon dioxide emissions		
Total electricity savings on 10% diversion to PR 126	MWh	190718.8463
Weighted average carbon emission factor	t/MWh	0.82
Reduction in carbon emissions on 10% area diversion to PR 126	t/MWh	156389.454
For the Electric Utility		
Ten percent of total tube wells***	number	133600
Annual electricity tariff from each tube well	$	15.07
Revenue from pricing of electricity	$	2.013 million
For the Farmer		
Incentive of Rs. 4200 per acre on 10% area	$	41.04 million

**Punjab State Power Corporation Limited; **Punjab Agriculture University; ***Tube well is irrigation pump.*
$1=Rs. 79.64

In case there is a financing shortfall, the cost of the monetary incentive could be partly borne out of the subsidy savings on electricity and partly by diverting some unproductive input subsidies. Punjab government disburses a range of input subsidies, which could be diverted to pay incentives to induce crop shifts. Some input subsidies are perceived as unproductive and ineffective by the farmers. For instance, during the survey, farmers showed their dissatisfaction about the delivery of subsidy provided for the purchase of agriculture machinery. There are alleged charges of misappropriation of the allocated funds. Economists and extension personnel have also argued in favor of cutting down on agriculture machinery subsidies to curb the over-mechanization of the agriculture sector and indebtedness of small and marginal farmers. It is contended that subsidies on big agriculture machinery are considered more beneficial for large farmers (Anand and Kaur, 2019). Instead these could be utilized for offering output price support for low-water crops, which would ensure more equitable distribution of financial resources. Another source for financing the monetary incentive to induce substitution by low-water rice variety of funds suggested by some experts could be the opportunity cost of diverting irrigation water for meeting human needs in water deficit areas of the country (Johl and Singh, 2017). Using this criterion, the revenue from the sale of water diverted to water deficit areas could be around $547 million.

An important finding of this study is that stability of the compensatory payment and rate of electricity charge over the medium term would encourage more substitution by low-water crops. It is found that farmers are quality conscious and willing to pay a price for better quality of supply. A potentially promising avenue for coordinated action between farmers and the electricity department could be investment in energy-efficient technology. A game theoretic approach found the potential of coordinated demand side measures on reducing energy use in Indian agriculture (Kimmich and Sagebiel, 2016). Summing up, Punjab farmers are not particularly keen on receiving low-quality free electricity; as reliable and stable farm power is rated far higher than free farm power.

Section 6: Conclusion

An increase in expected returns from substitution by low-water rice variety is at the heart of the transition to a system that uses less water to produce rice in Punjab. This study applied choice modeling to show that if compensation is guaranteed, farmers are more likely to opt for low-water crop which slows down water depletion, reduces electricity consumption, and brings down carbon dioxide emissions.

The demand analysis is based on two stated choice experiments conducted with 859 farmers in Punjab in 2021-22, shedding light on key attributes which drive rice variety substitution decisions. The econometric estimation analyzed farmers' valuations for compensatory payment to make variety shifts and acceptability of different levels of compensatory payment and electricity charge. Random effects probit and conditional logit model took account of the preference heterogeneity for area-based payment for substitution by short-duration rice and minimum assured price for basmati rice variety. It is found that there is a significant valuation for most of the compensatory payment attribute levels, suggesting that compensation at fairly moderate levels could be offered to induce substitution by low-water rice variety and encourage willingness to pay for electricity. The discrete choice methodology allowed the estimation of WTP and evaluation of possible pricing strategies that could incentivize the participation of a majority of farmers required to provide the optimal level of demand response. The results suggest that introducing relatively low monthly electricity and load-based electricity charge could encourage farmers' willingness to pay.

It is found that area-based compensation of Rs. 4200 per month for substitution by short-duration rice and minimum assured price of Rs. 3200/q for basmati variety would be accepted by about 74 percent of the farmers. About 66 percent and 58 percent of the farmers are willing to pay the fixed monthly electricity charge with an area-based payment of Rs. 4200 per acre for short-duration rice and minimum assured price of Rs. 3200 per quintal for basmati respectively. Acceptance of load-based electricity charge is 56 percent for incentive of Rs. 4500 per acre and 58 percent for Rs. 3500 per quintal for low-water rice variety. The cost-benefit analysis has revealed that the major portion of the cost of financing the compensation could be carved out of repurposing electricity subsidies.

The WTP is Rs. 99.46 ($1.24) per month for area-based payment of Rs. 4200 per acre and Rs. 112 ($1.40) per month for Rs. 4500 per acre for short-duration rice. WTP is Rs. 8.3(0.10)/HP/month for substitution compensation of Rs. 4200 per acre and Rs. 9.45(0.11)/HP/month for Rs. 4500 per acre for short-duration rice. The WTP is Rs. 74.4 ($0.93) per month for minimum assured price of Rs. 3200/q and Rs. 137.96 ($1.73) per month for Rs. 3500/q for basmati. The WTP is Rs. 4.12 ($0.05) /HP/month for Rs. 3200/q and Rs. 7.65 ($0.09)/HP/month for Rs. 3500/q minimum assured price for basmati. The WTP values are adequately high given the existing level of satisfaction with the quality and timing of electricity supply. However, improvements in the reliability of electricity cannot be financed out of the electricity charge at the existing level of satisfaction.

One limitation of this research is that it is based on hypothetical and stated choices of compensation schemes. Some randomness of choice on the farmer's side is therefore likely. The randomness of choice is expected to be heterogeneous across respondents. Segmented estimation is applied to understand the heterogeneity of choice behaviour. Some farmers may have higher willingness to pay and identifying them provides scope for introducing reform. University educated farmers are more likely to pay electricity bills with the offer of area-based payment and minimum assured price for substitution by low-water rice variety. Marginal farmers, medium farmers, and multiple tube well-owning farmers are likely to prefer load-based electricity charge with area-based payment. Farmers in the Malwa region are more likely to accept area-based payment for substitution by short-duration rice, while farmers in the Majha region are more favorably inclined towards substituting basmati rice with the offer of minimum assured price. Farmers in the Majha region show lower negative preferences for willingness to pay for electricity. The variation in valuation across different socio-economic-demographic characteristics and spatial spread proves that 'one size fits' all may not necessarily fit all.

This paper is the first step towards a full cost-benefit analysis of a more complex policy design and highlights the strategic opportunities for applying the toolbox of choice modeling to address the invidious energy-water-food nexus in India. Future work could explore heterogeneity in farmers' preferences for different crop varieties and willingness to pay for electricity. The direct impact of socio-economic and demographic characteristics on preferences can be examined as another extension of the baseline model. Consideration of attribute interactions could be an interesting extension of this work. The findings of this paper establish that identifying factors that influence farmers' preferences can be used to prepare potentially more cost-efficient and more widely acceptable diversification and energy pricing strategies. It is hoped that the selection and targeting of policy measures to tap the water and energy-saving potential of the farmers would be better informed by this line of research on behaviour, policy, and preferences in the future.

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Appendix:

Table 8: Interaction terms

Interaction term	Random effects probit		Conditional logit			Random effects probit		Conditional logit	
Payment_4200					AssurePric_3200				
Low load	-.0733	.1363	-.1281	.2514	Low load	-.2047	.1291	-.3535	.2272
Medium load	-.1284	.1466	-.2427	.2692	Medium load	-.1224	.1402	-.2175	.2464
High load	.2297	.2357	.4202	.4500	High load	-.3344	.2069	-.5847	.3569
Payment_4500					AssurePric_3500				
Low load	-.0382	.1377	-.0678	.2556	Low load	-.2782*	.1366	-.5025	.2552
Medium load	-.0591	.1483	-.1205	.2744	Medium load	-.2020	.1480	-.3768	.2756
High load	-.0102	.2359	.0107	.4450	High load	-.3548*	.2152	-.6211	.3941
Price_100					Price_100				
Low load	.0500	.1348	.1052	.2555	Low load	-.0713	.1288	-.0914	.2402
Medium load	.0710	.1458	.1337	.2762	Medium load	-.2128	.1398	-.3424	.2616
High load	-.4464*	.2319	-.8622	.4661	High load	-.1286	.2050	-.1850	.3805
Price_10					Price_10				
Low load	.1383	.1354	.2523	.2701	Low load	.0877	.1389	.1886	.2762
Medium load	.1163	.1464	.2221	.2916	Medium load	.0316	.1506	.0860	.2996
High load	-.3873*	.2330	-.8009	.4930	High load	-.0322	.2231	.0468	.4361
Payment_4200					AssurePric_3200				
Single well	.0184	.1511	.0099	.2815	Single well	-.2088	.1418	-.3450	.2490
Multiple well	-.2227	.1468	-.3929	.2723	Multiple well	-.1331	.1386	-.2367	.2430
Payment_4500					AssurePric_3500				
Single well	.1340	.1521	.2014	.2835	Single well	-.3394*	.1500	-.6063*	.2810
Multiple well	-.0719	.1476	-.1414	.2741	Multiple well	-.2243	.1470	-.4224	.2759
Price_100					Price_100				
Single well	.0562	.1499	.1591	.2894	Single well	-.1209	.1415	-.2104	.2643
Multiple well	.1138	.1459	.2448	.2822	Multiple well	-.1038	.1385	-.1415	.2579
Price_10					Price_10				
Single well	.1067	.1513	.2281	.3070	Single well	-.0783	.1525	-.1178	.3030
Multiple well	.2630*	.1471	.4898	.2984	Multiple well	.0641	.1488	.1696	.2941
Payment_4200					AssurePric_3200				
Marginal	-.1513	.2021	-.2233	.3715	Marginal	-.1852	.1919	-.2891	.3360
Small	-.0104	.1845	.0391	.3430	Small	-.1282	.1743	-.1842	.3063
Semi-Medium	-.0183	.1794	-.0439	.3316	Semi-Medium	-.2076	.1702	-.3543	.2971

Medium	-.3128*	.1816	-.4878	.3340	Medium	-.1657	.1734	-.3056	.3019
Large	-.0843	.2148	-.1404	.3956	Large	-.3338	.2034	-.5151	.3573
Payment_4500					AssurePric_3500				
Marginal	.0982	.2038	.1944	.3766	Marginal	-.0184	.1990	-.0152	.3666
Small	.0316	.1852	.1163	.3436	Small	-.0651	.1798	-.0805	.3303
Semi-Medium	.0799	.1803	.1235	.3328	Semi-Medium	-.1363	.1750	-.2629	.3196
Medium	-.0261	.1830	.0121	.3381	Medium	.0629	.1793	.0679	.3284
Large	.0209	.2163	.0335	.3984	Large	-.2343	.2091	-.3300	.3844
Price_100					Price_100				
Marginal	.2436	.1994	.4803	.3773	Marginal	.2180	.1893	.4008	.3557
Small	-.0249	.1826	-.0512	.3521	Small	.0891	.1715	.1279	.3264
Semi-Medium	.0360	.1787	.0910	.3424	Semi-Medium	.0433	.1671	.1228	.3155
Medium	.1611	.1809	.2931	.3462	Medium	.0957	.1707	.2562	.3201
Large	-.0013	.2136	.02544	.4076	Large	.0138	.2002	-.0413	.3851
Price_10					Price_10				
Marginal	.3932*	.2008	.7025*	.3981	Marginal	-.0141	.2026	.0238	.4023
Small	.0444	.1847	.0333	.3734	Small	-.1993	.1840	-.3280	.3703
Semi-Medium	.1480	.1801	.2595	.3617	Semi-Medium	-.0172	.1782	.0483	.3547
Medium	.3698*	.1820	.6180*	.3648	Medium	.0696	.1820	.2631	.3587
Large	.1784	.2140	.2940	.4285	Large	-.1822	.2161	-.3537	.4384
Payment_4200					AssurePric_3200				
Upto matriculate	-.1680	.1498	-.2539	.2757	Upto matriculate	-.1182	.1422	-.2117	.2504
Upto graduation	-.0876	.1548	-.1312	.2848	Upto graduation	-.0355	.1466	-.0947	.2577
Above graduate	.2650	.2398	.5557	.4596	Above graduate	-.0590	.2158	-.1071	.3774
Payment_4500					AssurePric_3500				
Upto matriculate	.1575	.1499	.2967	.2743	Upto matriculate	-.0157	.1475	-.0443	.2700
Upto graduation	.2029	.1551	.3615	.2839	Upto graduation	.0152	.1523	-.0089	.2784
Above graduation	.2348	.2388	.4862	.4493	Above graduation	.0384	.2235	.0745	.4121
Price_100					Price_100				
Upto matriculate	.2456*	.1487	.4780*	.2872	Upto matriculate	.0483	.1403	.1571	.2676
Upto graduation	.1739	.1539	.3465	.2966	Upto graduation	.0831	.1449	.2105	.2756
Above graduate	-.2434	.2389	-.6018	.4908	Above graduate	.0981	.2121	.1947	.4013
Price_10					Price_10				
Upto matriculate	.1351	.1481	.2868	.2988	Upto matriculate	.2938*	.1533	.5533*	.3115
Upto graduation	.1718	.1528	.3260	.3079	Upto graduation	.2006	.1583	.4221	.3212

Above graduate	-.2384	.2379	-.6298	.5117	Above graduate	.1404	.2311	.2632	.4664

**p<0.10*