Unlocking energy-water nexus and incentivizing energy-saving behavior in Indian agriculture
Discrete choice approach

Sukhgeet Kaur
Department of Land Economy
University of Cambridge

This dissertation is submitted
for the degree of Doctor of Philosophy

St Edmunds College,
9th October 2022

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification at the University of Cambridge or any other University or similar institution. This dissertation is the result of my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and acknowledgments. This dissertation contains fewer than 80,000 words including appendices, bibliography, footnotes, tables, and equations and has fewer than 150 figures.

Abstract

Title: Unlocking energy-water nexus and incentivizing energy-saving behavior in Indian agriculture - Discrete choice approach
Name: Sukhgeet Kaur

Replacing inefficient subsidies with better alternatives is a formidable task in developing countries. Reform is even more daunting when there is free supply of electricity in a sector that is the backbone of the economy. This thesis is set against the background of the policy of free supply of electricity to agriculture in India's agricultural state of Punjab. The emerging evidence-based assessment of sustainable alternatives to replace free access of electricity to agriculture from this study would be equally applicable to economies and geographies grappling with the problem of inefficient electricity subsidies. There are multiple possibilities as the interaction between water and energy sectors in agriculture is multilayered. This thesis examines farmers' preferences for innovative solutions collected with the help of discrete choice experiments involving groundbreaking field work. The work presented in this thesis is probably one of the first of its kind, to the best of the author's knowledge.

Despite mounting evidence that electricity subsidies to agriculture are fundamentally unsustainable, opposition to reform presents a problem for governments. Governments must be able to convince farmers to successfully advocate reform and unlock the water-energy nexus, which represents both a low-level policy equilibrium and a crisis in environmental governance. This PhD thesis based on four discrete choice experiments and complemented with insights from behavioral sciences examines the crucial role of preferences in predicting farmers' support for alternatives that compensate them for the losses associated with reforming subsidies. In the three chapters, micro-level data from 3436 interactions with farmers in Punjab yielding 36078 responses is econometrically analyzed to explore preferences and behavioral responses for interventions that can potentially keep the electricity subsidies as low as practically possible and incentivize sustainable use of water and energy in agriculture. The research suggests that the consideration of

heterogeneity in preferences and valuations for energy-saving interventions can help in reconciling the achievement of reform objectives with securing public support and protection of vulnerable groups. The first chapter presents a summary, and the second chapter presents an introduction to the study. The sixth chapter presents the conclusions of the study. The third, fourth and fifth chapters examine farmers preferences with the help of three discrete choice experiments to alternatives that can replace free electricity and ensure more sustainable resource use in Indian agriculture.

The third chapter examines farmers' preferences and response behavior to the potential introduction of economic incentives for inducing the adoption of low-water rice varieties and the willingness to trade off free electricity for these incentives. The estimation strategy applies conditional logit and random effects probit to highlight positive valuations for different economic incentives – area-based payments and minimum assured prices which can drive adoption decisions. The chapter shows that willingness to pay depends on the type of electricity tariff, which could be exploited to encourage payment behaviour and bring about reductions in energy use.

The fourth chapter applies the econometric estimation approach developed in the third chapter to an original data set of preferences to examine the potential for introducing an annual free electricity entitlement, reward system and incentive-penalizing tariffs in inducing acceptance of metering with payment option and adoption of energy-saving behavior among farmers. The results of the choice experiment demonstrate acceptance of the annual limit of free electricity, reward, and incentive for unused units, which can serve as important determinants in the transition towards metered consumption in Punjab agriculture. Further, designing behavioral interventions around small rewards and punishments can be useful, even if penalties are rarely used.

Finally, the fifth chapter sheds light on farmers' preferences for financial incentives to promote the diffusion of solar PV irrigation pumps in Punjab agriculture. The flexible mixed logit formulation is additionally applied to improve the willingness to pay/willingness to accept estimates and economic evaluations. The results show that initial subsidies have a significant impact on encouraging installation of solar irrigation pumps, whereas the buyback option has a positive effect on encouraging acceptance of grid connected solar irrigation pumps. The effect of the type of purchase option and contextual factors is considered on the acceptance of grid-connected solar pumps and willingness to pay. The approach attempts to predict farmers' preferences for an integrated platform of distributed solar power generation in the future.

The three studies illustrate strong preferences for the replacement of high-water intensive crop varieties by low-water rice varieties, substitution of unmetered supply of free electricity by metered consumption, and adoption of renewable energy in the energy mix with the help of moderate incentives offered to farmers. The cost-benefit analysis shows that the potential savings from economic and environmental benefits could compensate for the welfare losses. These complementary reform strategies have a large potential for the protection of water resources, which have reached a critical level, the reduction of electricity subsidy to agriculture, the magnitude of which has become unsustainable to continue for government budgets and the adoption of energy saving behaviour among Punjab farmers who are perceived to be opposed to reform. The refined econometric estimations shed light on the peculiarities of farmer heterogeneity, and the usefulness of deploying differentiated incentives to promote participation in electricity saving and energy conservation strategies. The findings have practical implications for environmental governance and agricultural development and contribute to an understanding of incentivizing energy-saving behavior in agriculture in a developing country. The study establishes that there is room for reform that can be widely acceptable to all stakeholders.

Acknowledgments

First, I must profoundly thank Dr. Michael Pollitt, Professor of Business Economics at the University of Cambridge, who was an outstanding PhD Supervisor, going far beyond the call of duty. In the last three years of doctoral research, he has been a huge source of knowledge, inspiration, and invaluable guidance. This thesis has materialized only because of his continued encouragement and tremendous support. I could not have weathered the storms without his wisdom and compassion. I felt greatly motivated and encouraged every time I attended a meeting with him. I cannot thank him enough for his constant help, for spending endless hours reading my work and for giving brilliant suggestions which always resulted in improved versions of documents. I could not have wished for a better Supervisor, and I feel honored to conduct this research under his excellent supervision.

I am also grateful to the many farmers in Punjab who invited me into their homes, allowed me to ask provocative questions, and generously shared their thoughts and ideas with me. In addition to the farmers, many eminent persons spared their valuable time for the author. It would be impossible to list all the names, but a few deserve my sincere thanks. First, Dr. Manmohan Singh who gave his unfailing support and generous assistance in interviewing the large number of farmers across Punjab. I take this opportunity to express gratitude from my heart for his tremendous help. I am deeply grateful to Dr. Ramesh Chand, Ajay Pal Singh, Dr. Ajmer Singh Brar, Sukhjit Singh and PC Bains for their helpful suggestions; Dr. Abdul Rawoof Pinjari for providing access to the IT facilities at the Indian Institute of Science, Bangalore; Parveen Mahto and Late Dr. Anil Thakur for their generous recommendations on my funding applications; Dr. David Howarth and Dr. Jorge Vinuales at my Department and in particular to Hugo Hocknell for brilliantly navigating the paperwork and to the eminent economists at the Energy Policy Research Group who nurtured my academic development. With a deep sense of humility, I express my heartfelt gratitude to the late Dr. Ajit Singh, Professor of Economics at the University of Cambridge for his inspiration.

I gratefully acknowledge the grant of Domestic Funding of Foreign Training from the Department of Personnel and Training Government of India, Routledge Round Table Commonwealth Studentship Award, Trinity-Henry Barlow Scholarship, and grants from the Association of Sikh Professionals, and Sidney Perry Foundation, which significantly helped in completing my PhD.

I would not be in this position without my family. Warm heartedly, my thanks go to my siblings – Ravneet, Gurmeen, and Harsimrat, and to my brothers in law Dr. Inderjit Singh, Sukhdev Singh, and Major General Jang Bahadur Singh for their endless support. I thank Alok Kumar, my brilliant and loving husband, for his continuous help in this journey. My thanks to my good friends Calum, Steph, and Paul for their affection and cooperation.

I am incredibly grateful to my dear and loving parents, father Hardial Singh and mother Pritpaul Kaur, who unconditionally supported, encouraged, and motivated me throughout this journey. They always believed in me, and I drew immense strength from their confidence in my ability and capacity for sustained hard work. I hope I have made them proud. With lots of love, I dedicate this thesis to them.

As a devotee of God, I would like to thank the Almighty for successfully completing this thesis. Every step of this arduous journey, he blessed me. When I felt low, courage came from him. He gave me encouragement and strength during the most challenging moments of completing this study. I am truly grateful to God for his endless sustenance, mercy, grace, and love in achieving this goal. At the end, I close with a prayer for the welfare of every living being in this world.

Table of Contents

List of Abbreviations

DCE	Discrete choice experiment
MSP	Minimum support price
PAU	Punjab Agriculture University
PEDA	Punjab Energy Devolvement Agency
PFC	Power Finance Corporation
PSPCL	Punjab State Power Corporation Limited
PSERC	Punjab State Electricity Regulatory Commission
PSFC	Punjab State Farmers and Farm Workers Commission
PV	Photovoltaic
WTA	Willingness to Accept
WTP	Willingness to Pay

List of Figures

1 Chapter: Summary

Policymakers in developing countries are grappling with undesirable policies which reduce economic welfare and result in inefficient resource allocation. One such policy is electricity subsidy to agriculture in developing countries which contributes to groundwater overexploitation and increases the state's fiscal burden (Badiani and Jessoe, 2017). The persistence of policies perpetuating low-level equilibrium is attributed to a lack of public support for reform in developing countries (Alkon and Urpelainen, 2018). This PhD thesis analyses farmers' preferences and behavioral responses to alternatives that compensate them for the losses associated with subsidy reform. Discrete choice experiments are applied in Punjab traditionally known as India's breadbasket and facing adverse economic and environmental consequences of the free electricity policy to agriculture. In the three chapters, micro-level data is exploited to econometrically explore farmers' preferences and willingness to pay/willingness to accept the strategies reducing subsidies. The results suggest that consideration of heterogeneity in farmers' preferences and valuations for incentives could encourage energy-saving behavior and acceptance of sustainable resource use. The findings of this thesis would be especially beneficial as the discrete choice method is applied for the first time (to the best of the author's knowledge) in Punjab, which urgently requires information and innovative strategies for incentivizing energy-saving behavior in agriculture. Chapter 1 contains a summary of the thesis and Chapter 2 presents an introduction to the study. Chapter 6 offers conclusions.

1. The key question of the third chapter, 'A discrete choice experiment to estimate farmers' preferences for low-water rice variety in Punjab' is to understand Punjab farmers' preferences, attitudes, and response behavior to the potential introduction of economic incentives for inducing adoption of low-water rice variety and willingness to trade-off free electricity for these incentives.

Background: In Punjab, paddy cultivation occupies 76 percent of the cultivated area and generates a market surplus, second to Thailand at the global level. A combination of factors such as assured procurement, free electricity for irrigation, and perception of higher returns contributes to high dependence on the rice-wheat cultivation cycle. Rice accounts for 80 percent of water use in the Kharif season (Kaur et al., 2012). The rapidly depleting water table level and high toxicity of the soil from overuse of fertilizers and pesticides are attributed to farmers' preference for rice, particularly the long-duration Pusa 44 variety. Savings of groundwater and energy are feasible by choosing less water-intensive varieties of rice. A major policy aim has been a diversion of the area to early maturing and less water-intensive rice varieties such as PR 121, PR 126, and basmati. However, farmers face many barriers to adopting short-duration rice varieties, such as lower net returns, vulnerability to pests and vagaries of weather, the predominance of broken grain, price volatility, and other marketing challenges. At the same time, there is accumulating evidence of the use of incentive schemes to motivate crop changes and sustainable practices in several countries (Bopp et al., 2019). In the context of the high preference of Punjab farmers for rice, area-based payments and assured prices have been seriously considered as potential policy vehicles for encouraging the adoption of low-water rice varieties.

However, little is known about farmers' preferences for incentives and as a result their relative effectiveness in encouraging the adoption of low-water rice varieties. A related problem is the role of free electricity in boosting the cultivation of the long-duration rice variety. Unwillingness to give up free electricity is a major obstacle to pricing reforms. There is a dearth of information in the literature about the determinants of farmers' willingness to pay for electricity with better crop returns. Moving away from water-intensive rice varieties will result in lower electricity and water consumption. The question is whether the incentive offered for inducing the adoption of water-saving varieties can also motivate farmers to pay for electricity on a flat rate or connected load basis. It is against this background that the third chapter applies a choice experiment to assess farmers' readiness to accept incentives for a shift to the low-water rice varieties, namely PR 121 or PR 126 and basmati. In this choice experiment, farmers are presented with two alternatives, to either accept the incentive to shift to low-water rice variety and pay the electric charge or remain with the status quo. There are two attributes with three levels each – the amount of incentive for substituting high-water rice variety with low-water rice variety and the level of electric charge. There are nine choice sets, and the farmer is asked to choose the most preferred alternative from each choice set.

Gathering evidence about farmers' response to incentives to induce crop variety changes and willingness to pay electricity tariffs is instructive because these choices provide direct insights into the value placed by farmers on incentives for crop variety changes and associated trade-offs with free electricity. The study explores the effect of incentives on farmers' willingness to pay for electricity and examines the drivers and determinants of willingness to pay/willingness to accept. This study is deemed necessary to empirically determine the level of incentives farmers are willing to accept to shift to alternative rice varieties capable of reversing the over-exploitation of water and enhancing income levels.

2. The fourth chapter titled, 'Using rewards and penalties to incentivize energy saving behavior in agriculture – Evidence from a choice experiment in Punjab' applies a choice experiment to assess the effect of annual free energy limit and a combination of incentive-penalizing tariffs on inducing a shift to metered consumption in Punjab agriculture.

Background: The Electricity Act 2003 has mandated distribution utilities to supply electricity only through the installation of a correct meter. This is a sound prescription for Punjab which supplies free electricity to agriculture without the use of meters. Free electricity is a financial drag on fiscal resources. The unmetered and unverifiable agricultural power supply is the prime cause of the bankruptcy of distribution utilities in India. Lack of financial discipline deteriorates their capabilities to maintain infrastructure and add to power generation capacity. A major implication of the absence of verifiable energy accounting due to unmetered consumption is the camouflaging of the inefficiency and theft of electricity. Unmetered electricity consumption increases groundwater extraction and imposes long-term costs on the sustainability of aquifers and agricultural development in the future. A return to metering has potential benefits of reducing subsidy burden, enforcing transmission and distribution efficiency in power utilities, and bringing about sustainable use of water and electricity.

While metering and pricing of electricity is arguably the best practice, enforcement faces serious challenges. Barriers to reform associated with the political economy are the most difficult. The easiest way to reform is the direct cash transfer of electricity subsidy as an income subsidy which would rationalize production decisions, reduce leakages, incentivize rational use of inputs, and contribute to fixation of minimum support price on a realistic basis. This would also make the process of crop diversification self-propelling and result in savings of scarce production resources including water and power (Johl et al., 2014). However, disbursing large upfront cash transfers is likely to burden the existing administrative system. Determining the entitlement of each farmer based on the crops being grown and fixing the likely power consumption dependent on the groundwater level, amount of precipitation etc., and disbursing the calculated amount would entail huge administrative problems imposing additional costs on the system. Such a change-over would also involve billing and collection of tariff revenue from 1.3 million tube well-owning farmers. Further, with about 60 percent of agriculture depending on groundwater irrigation and free electricity, the adverse effects in terms of the skewed distributional impact on vulnerable farming households make subsidy withdrawal appear inequitable and thereby politically difficult. Since the first-best economic solutions are unlikely to attract widespread political support and public acceptance, the objective of the fourth chapter is to investigate the acceptance of the second-best solutions – electricity entitlement and cash incentive scheme in setting 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 behavior among consumers (Bor et al., 2004).

Drawing upon insights from behavioral approaches and international experience with innovative tariff structures, the fourth chapter examines farmers' preferences for the replacement of unlimited free electricity with an annual limit of free electricity as a method of reducing electricity subsidies, the effect of reward on increasing voluntary acceptance of meter installation among Punjab farmers, and the effect of the combination of incentive and penalty schemes in encouraging the desired behavioral change in electricity and groundwater use.

The analysis based on micro-level data gathered about farmers' preferences from the choice experiment examines the relative merits of the above-mentioned strategies. 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.

3. The fifth chapter titled, 'Farmers' preferences for incentives on solar pumps - Evidence from a choice experiment in Punjab' investigates farmers' preferences for grid-connected solar pumps and feeder-level solarization in agriculture. The study aims to

evaluate the effect of changes in subsidy level, feed-in-tariff rate, and income from the sale of surplus energy which may influence the adoption decisions of farmers.

Background: Previous studies have investigated preferences for green energy sources and identified consumers' motivations and barriers to the adoption of renewable energy, including solar energy. However, few studies examine policies that can motivate the adoption of solar technology in agriculture. Integrating solar photovoltaics in the agriculture sector offers an opportunity to decarbonize electricity systems in India. Given the interlocking challenges of the water-energy nexus, solar pumps can be a potential game-changer in simultaneously extending clean energy access, and replacing expensive diesel pumps, while reducing the electricity subsidy burden and addressing the issue of depleting groundwater.

The government has been making an increasing pitch for solar pumps by providing substantial subsidies on the capital cost of solar PV pumps and offering attractive surplus energy buyback rates to incentivize adoption. Expanding solar irrigation in agriculture remains a significant challenge. One of the possible reasons for the slow adoption is that policies are framed by the government and adoption decisions are taken by the farmer who may be using different assessment criteria. Farmers' adoption decisions are influenced by several factors including financial capability, ease of use, risk of theft, water discharge, level of knowledge and awareness, economic and environmental benefits, etc. Despite the reduced cost of solar panels and government subsidies on the cost of a pump, the penetration of photovoltaics in agriculture is limited, even though solar pumps are an extremely promising alternative to conventional electric pumps. This is because solar pumps require a much larger initial investment while fossil fuel-based energy has higher annual costs. The level of incentives provided through subsidy schemes seems inadequate to make a substantial impact on adoption decisions in Punjab. Improving the affordability and profitability of installing solar pumps could markedly increase the adoption of solar pumps in agriculture.

This study reports a discrete choice experiment to evaluate whether improving the level of financial incentives can potentially increase the adoption of grid-connected solar pumps in Punjab. The study investigates farmers' preferences for different forms of financial incentives, particularly the influence of the level of subsidy and feed-in-tariff rate on the adoption of solar pumps. The chapter also studies the comparative valuation of farmers for receiving income from the sale of excess electricity in cash or as an offset in the residential electricity bill and whether the type of transfer influences the uptake of solar irrigation pumps. Farmers' preferences for investing in solar water pumps at an individual farm or accepting feeder-level solarization catering to many farms are also studied. This chapter addresses the gap in the literature by empirically examining the effect of incentives on installing grid-connected solar pumps, which can serve as an effective alternative to the highly subsidized electric pumps in Punjab. The findings of this study have practical significance as Punjab is witnessing a critical groundwater situation and solarization presents an innovative approach to solve the invidious energy-water nexus.

To conclude, this PhD thesis applies choice experiment methodology to examine the role of economic incentives in inducing a switch over to low-water rice, acceptance of metered electricity consumption and changing the energy mix in agriculture. These interventions have the potential to keep the electricity subsidies as low as practically possible and incentivize the adoption of more effective ways of achieving sustainable use of water and energy in agriculture. The three studies illustrate that farmers' preferences for incentives and sustainable strategies are heterogeneous and that differentiated incentives can promote participation. The refined econometric estimations in this thesis shed light on the peculiarities of farmer heterogeneity, which can help to prepare future schemes which are better tailored to farmers' preferences, and thus potentially more cost-efficient and more widely acceptable.

While the focus of the thesis is on addressing the energy-water nexus borne out of the inter-linkages between groundwater irrigation, and agricultural electricity consumption, the implications of this nexus inevitably involve food supply and sustenance of agricultural production systems. The free electricity driven electric irrigation pumps have helped in increasing food production but are also encouraging over pumping of groundwater. As the over extraction of the previously abundant and reliable groundwater persists, this constitutes a major threat to the future sustainability of agriculture. Punjab, known as India's granary, faces threat of desertification in the most productive districts. In addition, climate change is likely to present additional uncertainties to availability of water and energy sources over time and space.

As the global population grows, consumption of water, energy and food will also increase, placing stress on these three sectors, raising the importance of managing these three resources. There is an ongoing debate about how best to feed the growing world population in the long run and associated implications for research and development. Research is focusing on meeting the growing demand for food, water, and energy for a growing population in developing countries. With rising populations and appetites for these limited resources, research into key connections of energy-water nexus to food will occupy center stage in the future. The aim of this thesis is to adopt a wider perspective and examine the acceptability of solutions emerging from the interactions between water, energy, and agriculture.

References

Alkon, M., & Urpelainen, J. (2018). Trust in Government and Subsidy Reform: Evidence from a Survey of Indian Farmers. Studies in Comparative International Development, 53(4), 449-476.

Badiani, R., & Jessoe, K. (2013). The impact of electricity subsidies on groundwater extraction and agricultural production. Department of Agriculture and Resource Economics Working Paper, University of California Davis.

Bopp, C., Engler, A., Poortvliet, P. M., & Jara-Rojas, R. (2019). The role of farmers' intrinsic motivation in the effectiveness of policy incentives to promote sustainable agricultural practices. Journal of Environmental Management, 244, 320-327.

Bor, Y. J., Chien, Y. L., & Hsu, E. (2004). The market-incentive recycling system for waste packaging containers in Taiwan. Environmental Science & Policy, 7(6), 509–523.

Johl, S. S., Sidhu, R. S., & Vatta, K. (2014). Natural Resources Management in Punjab Agriculture: Challenges and Way Forward. Discussion Paper Centers for International Project Trust, New Delhi.

Kaur, B., Singh, S., Garg, B. R., Singh, J. M., & Singh, J. (2012). Enhancing water productivity through on-farm resource conservation technology in Punjab agriculture. Agricultural Economics Research Review, 25(347-2016-16901), 79-85.

Zekri, S. (2008). Using economic incentives and regulations to reduce seawater intrusion in the Batinah coastal area of Oman. Agricultural Water Management, 95(3), 243-252.

2. Chapter: Introduction to Alternatives to Electricity Subsidies in Agriculture in Developing Countries

Groundwater irrigation, largely fueled by electricity subsidies contributed to increased agricultural productivity, reduced food prices, and increased demand for agricultural labor in India (Badiani and Jessoe, 2013). However, electricity subsidies impose a rising fiscal burden on the state, reduce the incentive to conserve groundwater and coordinate the use of groundwater and surface water, discourage investment in rural electricity infrastructure and large farmers benefit more from them than small farmers (Birner, et al., 2007). The availability of subsidized electricity has brought groundwater irrigation to the forefront, but it does not incentivize farmers to use the precious resource efficiently (Kumar et al., 2022).

Governments have failed to make a dent in the increasingly uneconomic practice of subsidizing electricity for agriculture, as policies replacing subsidies lack public support, particularly so in Punjab. The state faces the worst economic and environmental costs of the policy of free electricity for agriculture. Free electricity to the farm sector is often quoted as the main precursor to the increase in the rice area, over-exploitation of groundwater, and as an obstacle to diversification (Singh 2012). Making a transition to efficient resource use is a challenge. As supply is free, farmers resent any change. Further, the effect of eliminating subsidies can be even worse than continuing with the current policy because of the impact on poor farmers and food security. The inefficient policy with sub-optimal consequences for all stakeholders persists despite alternatives that can make everyone better off.

Creating appropriate alternatives to subsidies that can compensate those who benefit from subsidies is a common problem faced by developing countries. The critical challenge is realigning alternatives with farmers' preferences such that farmers are compensated for the costs associated with replacing inefficient policies. There is abundant literature emphasizing the role of financial incentives in inducing energy-saving behavior (Winett et al., 1978, Petersen et al., 2007, McClelland and Cook, 1980). Financial incentives and understanding factors determining farmers' decision-making hold the potential for reducing electricity consumption and thereby groundwater overdraft.

The focus of this study is on Punjab, where there is huge potential for realigning the electricity subsidies with a more efficient allocation of resources and sustainable solutions. Understanding the dynamics of farmers' preferences and the role of financial incentives in promoting pro-environment behavior is an under-researched area in Punjab.

The remainder of this chapter is organized as follows. Section 2.1 describes the study area. Section 2.2 includes a discussion on the link between electricity consumption and water use. Section 2.3 presents a brief description of the extent, magnitude, and distribution of agricultural electricity subsidies in Punjab and India. Section 2.4 outlines the negative externalities of electricity subsidies upon agriculture, utilities, and farmers in separate subsections. Section 2.5 examines the policy interventions by the state to tackle the problem, outlines the proposed solutions, and describes the major benefits and barriers to the reform process, including the economic, social, and environmental consequences of subsidy phase-out and issues related to the political economy of electricity subsidy reform. Section 2.6 addresses the challenges to reform and advances the argument of compensation and stakeholder consultation as a proposed strategy. Section 2.7 describes the relevance of the discrete choice experiment approach and the theoretical framework. Section 2.8 presents the materials and methods for this study with details of questionnaire development and survey administration. Section 2.9 shows the results of the descriptive statistics of the sampled farmers. Finally, section 2.10 offers the conclusions.

2.1: Study area

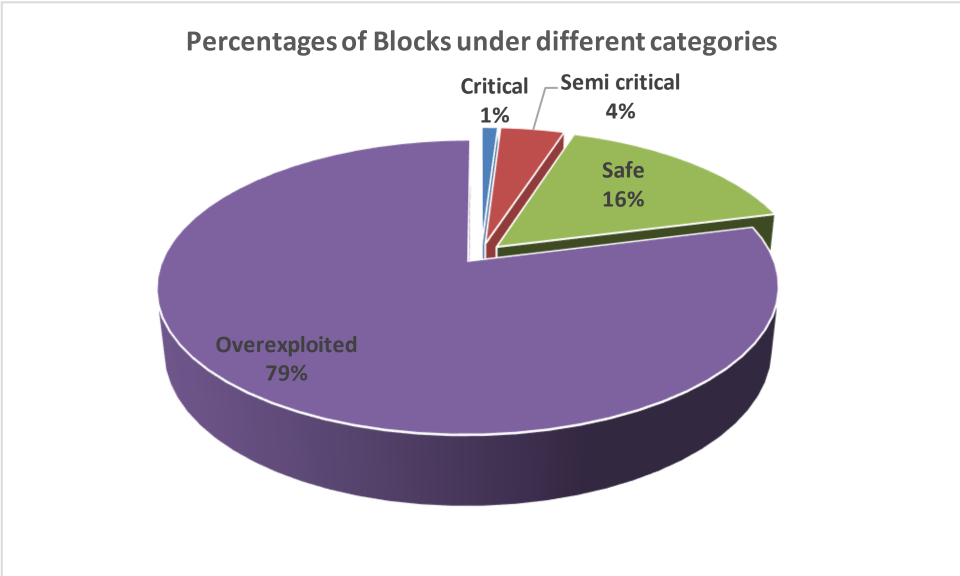
Punjab is one of the prominent agrarian states of India. It is located in north-western India and extends between the latitudes 29.30° North to 32.32° North and longitudes 73.55° East to 76.50° East covering an area of 5.0 million hectares. With over 27 million population, it has 23 districts, 93 tehsils, and 12581 villages. There are six agro-climatic zones, which include the sub-mountainous region, undulating plain region, central plain region, western plain region, western region, and flood plain region. These regions have rainfall variations from 165 mm to 2000 mm annually and climate from humid to cold arid and extremely arid. The variations in soil range from hill soil, terai, brown hill, and alluvial to the desert. The contribution of Punjab to agriculture and India's self-reliance on food has been remarkable. The state has the highest percentage of 98 percent net irrigated area and the highest irrigation intensity at 190 percent (Statistical Abstract, 2020). The gross cropped area is 79,38,517 hectares, out of which area sown more than once is 38,60,014 hectares. The cropping intensity is 195 percent. Punjab has the 15th largest economy and ranks ninth on the Human Development Index among states in India.

Figure 2:1:District Map of Punjab

Source: Government of Punjab, India

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. The cities in Doaba include Jalandhar, Hoshiarpur, Nawanshahr, and Kapurthala. Malwa is the region to the south of river Sutlej and makes up a large part of the state comprising more than 11 districts. Cities such as Ludhiana, Rupnagar, Patiala, Sangrur, Bhatinda, Mansa, Ferozepur, Rajpura, Moga, and SAS Nagar are located in the Malwa region. Southern Malwa is also famous for cotton farming (Department of Rural Development, Punjab).

Being one of the most agriculturally productive regions in Asia, Punjab has witnessed a continuous increase in groundwater use and the energy intensity of agriculture. Punjab agriculture depends on groundwater and has recently been experiencing an alarming decline in water table levels. The beginning of this crisis can be traced back to the spectacular agricultural transformation beginning in the 1960s with the introduction of mechanized farming. Tractors replaced animal power, and electric and diesel pumps replaced Persian wheels for drawing underground water. Punjab successfully embarked upon agriculture intensification supported by subsidized inputs and guaranteed procurement prices. Huge investments were made in rural electrification and groundwater irrigation. Groundwater irrigation accounted for 71 percent of the net irrigated area in 2019-20 (Statistical Abstract, 2020). With only 1.53 percent of the total land area, Punjab has been contributing 35-40 percent of wheat and 25-30 percent of rice to the Central Pool during the last decade. Despite being a traditionally non-rice growing area, Punjab had the highest productivity of wheat and rice during 2017-18 among Indian States (Statistics of Punjab Agriculture, 2020). Motivated by free electricity (*flat rates were replaced by a free power policy in 1997*) and assured procurement, farmers continued to increase rice cultivation in predominantly well-irrigated areas. As a result, water started receding at an alarming rate with withdrawal being more than annual recharge. Out of 138 blocks (*blocks are development units of a district*), 109 blocks are overexploited (*groundwater extraction is more than 100 percent*).

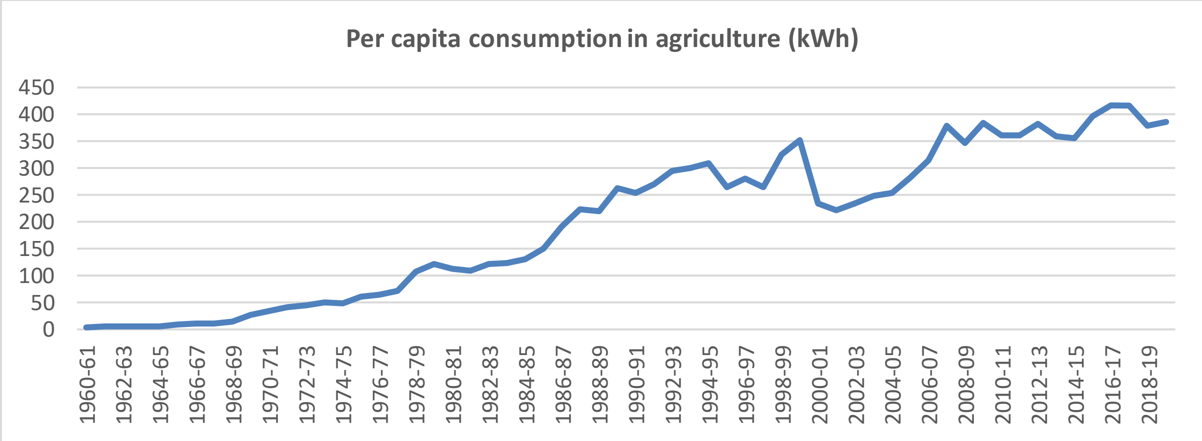


Source: Report Punjab Groundwater Resources 2017

Figure 2:2:Overexploited Blocks in Punjab

2.2: Link between electricity consumption and water

Agricultural electricity consumption in Punjab increased from 211 million kWh in 1965 to 12000 million kWh in 2020. As a share of total consumption, the share of agriculture decreased from 43.7 percent in 1980-81 to 21.8 percent in 2018-19. However, growth in new connections resulted in a fivefold increase in the number of agriculture consumers from 278184 to 1385549, with the annual per capita sale of electricity for agriculture (per farmer) climbing from 111.97 kWh to 378.48 kWh over the same period.



Source: Data sourced from EPW India Time Series

Figure 2:3 Increase in per capita consumption of electricity in agriculture from 1960 to 2019

The increase in electricity consumption reflects farmers' preferences for electric pumps to draw irrigation water. At an empirical level, hydrologists have established a link between increasing energy consumption and falling groundwater levels (Smith et al., 2015) in the following equation:

$$v = \frac{Y_h D}{367Ķ}$$

where v represents the hydraulic energy consumption (in GWh), Y_h represents the volume of groundwater pumped (in million cubic meters), D shows the depth of groundwater (in meters), and K is a physical constant multiplied by pumping efficiency Ķ (0 ≤ K≤ 1). This relationship has implications for the interlocking challenge of conserving water and energy in developing countries. This helps in understanding the role of free electricity in contributing to falling water table levels. More groundwater is extracted than the rate of replenishment as a farmer uses the available free electricity to pump groundwater for which little is paid at the price of electricity.

This situation can be conceptualized with the famous 'Tragedy of the Commons' model (Hardin 1968). An individual farmer considers the cost-benefit situation on his land, disregarding the adverse effect on others. Groundwater being a non-excludable good, the marginal private cost of pumping water is less than the marginal social cost and the quantity of water consumed is more than the socially optimum level.

As a large number of electricity connections in agriculture are unmetered in Punjab, the official figures for electricity consumption may not be accurate. A study reported that the utility's estimate of pump usage for unmetered farmers was significantly higher at 64 percent than actual farm use in Haryana. The higher unaccounted for transmission and distribution losses were likely due to theft and pilferage outside of the agriculture sector (Monari and Mostefai, 2001). An agency appointed by the utility in Punjab for the estimation of agriculture consumption reported a higher variation of 11 percent between the consumption reported by the Board and that computed by the Agency for the first three quarters of 2008-09 (PSERC Tariff order 2009). It is observed that theft increases with the intensity of tube wells or irrigation pumps, suggesting that it is linked to unmetered electricity use by farmers (Golden and Min, 2012).

2.2.1: Regulatory and market setting

At the time of independence, the Electricity (Supply) Act, 1948 was enacted to create the State Electricity Boards. Punjab State Electricity Board (PSEB) was a statutory body formed on 1.2.1959 under the Act. Subsequently with the re-organization of the erstwhile State of Punjab under the Punjab Re-organization Act 1966 this form came into existence w.e.f. 1st May 1967. At the all-India level, the legal framework was amended in 1991 and 1998 to facilitate private investment in generation and transmission, which enabled private entities to sell or transmit power only through long-term contracts with state-owned entities. Regulatory commissions were set up under the 1998 Act. Seven 'reforming' states (Haryana, Andhra Pradesh, Uttar Pradesh, Karnataka, Rajasthan, and Delhi) initially enacted their own laws and unbundled their integrated State Electricity Boards into generating, transmission and distribution companies, to be regulated by an independent regulatory commission in each state. Though a welcome move, this could only have a limited impact on the state-owned monopolies. These piecemeal changes in the name of reform were not able to arrest the deterioration of the industry (Haldea 2001).

The government of Punjab unbundled Punjab State Electrcity Board into Punjab State Power Corporation Limited (Powercom) and Punjab State Transmission Corporation Limited (Transco) in 2010. Feeders supplying power to Agriculture pump sets have been segregated and are metered in Punjab for a large section of agricultural consumers. Separating non-farm rural and farm rural feeders was helpful in better load management and meeting non-farm needs of the rural sector. Remaining 278 mixed feeders in the Kandi belt are being covered for feeder segregation under the current policy.

Based on the guidelines and implementation parameters prepared by the Central Electricity Regulatory Commission, tariff orders are generally passed every year by State Electricity Regulatory Commissions. The distribution revenue requirement is calculated based on the forecast cost of energy and wheeling charges to be paid for transmission. Annual revenue requirement and average tariff is determined after accounting for allowed losses. An evaluation or true up exercise carried out at the end of each tariff period considers revisions to costs and reviews determination of annual revenue requirement. The State Government releases a lump sum amount of subsidy as compensation. Ideally these disbursements should be made in advance, however in practice, there are delayed reimbursements made to the utilities. The subsidy received can be lower than the subsidy billed by the utility. Retail tariffs for each category of consumer are determined on the basis of previous tariff structures and state policies.

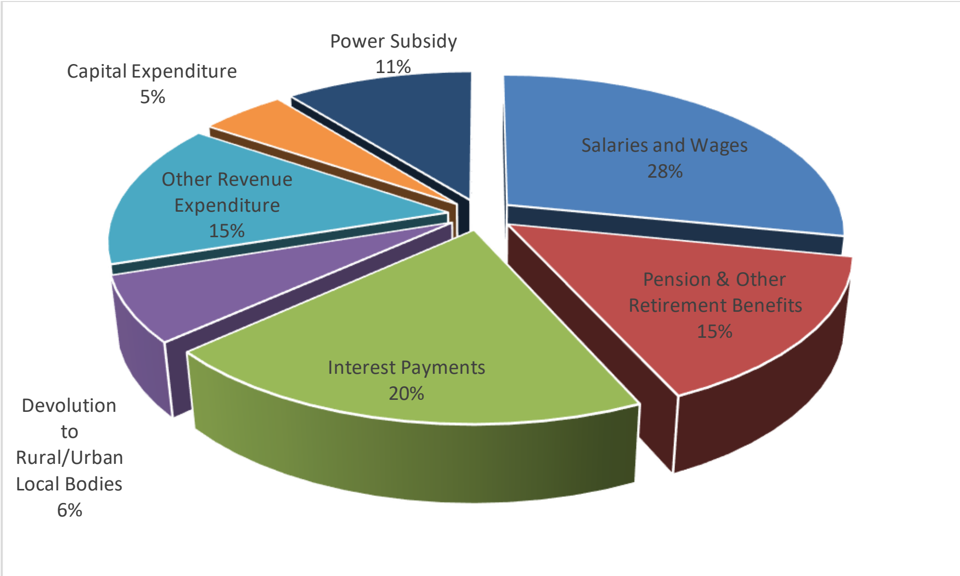
It is estimated that utilities in India incur an average revenue loss of Rs. 0.36 for every kilowatt hour of electricity supplied (Wong et al., 2022). The cost recovery gap is a result of non-cost reflective electricity tariffs (subsidized tariffs) as well as non-technical losses due to illegal wire use, meter-tampering, erroneous billing, improper recording of consumption, and non-payment. Losses incurred by distribution companies hamper their ability to provide adequate and reliable supply to consumers. Quality of supply results in consumer’s reluctance to pay and forms a vicious cycle of non-payment and poor supply (Blankenship et al., 2019). While the losses are a result of gaps in distribution companies’ monitoring efforts and consumer’s non-compliance, the non-optimal tariffs are set due to various social and political reasons, such as providing affordable electricity for the economically disadvantaged and for electoral advantages during election years.

Free and unconditional supply of electricity to agriculture, introduced for social and political reasons has been associated with several negative fallouts - declining groundwater levels, stagnant or declining agricultural productivity, deteriorating service quality, bankrupt SEBs and mounting revenue deficits (Gulati 2015). The long-term sustainability of agriculture and environment is threatened due to the fall in the water table, increasing soil fertility imbalance, and appearance of new pests and weeds. This crisis is likely to get severe with climate change. Changes in climate may be a hindrance in the future in pursuing sustainable economic growth, as economic activities such as agriculture are overtly climate sensitive.

The above clearly brings out that notwithstanding the inaccuracy in the measurement of electricity consumption, the provision of low-cost farm power represents one of the most significant and expensive subsidies to agriculture. It is associated with several negative externalities with far-reaching adverse consequences and ultimately harms the intended beneficiaries. The delivery of free electricity to agriculture is fraught with many problems, as outlined below.

2.3: Extent, magnitude, and distribution of electricity subsidies

The sheer size of the electricity subsidy is a burden on Punjab Government's budget, which reimburses the entire amount booked by the Electricity Regulator. The electricity subsidy bill on the state government has increased from \$214.3 million (Rs. 16590 million) in 2000 to \$782.9 million (Rs. 56700 million) in 2019. Free electricity to agriculture accounted for about 95 percent of the total subsidy disbursed by the Punjab Government in 2018-19. Electricity subsidies deplete fiscal resources (Koplow 2004) and come at the cost of other social programs (Badiani and Jessoe, 2018). In the case of Punjab, electricity subsidies account for 11 percent of the Punjab Government's total expenditure. The recurring subsidy expenditure could be a contributory factor to the huge debt of \$32254.4 million (Rs. 249673 crores) on the Punjab government (Finance Department, Government of Punjab 2020).



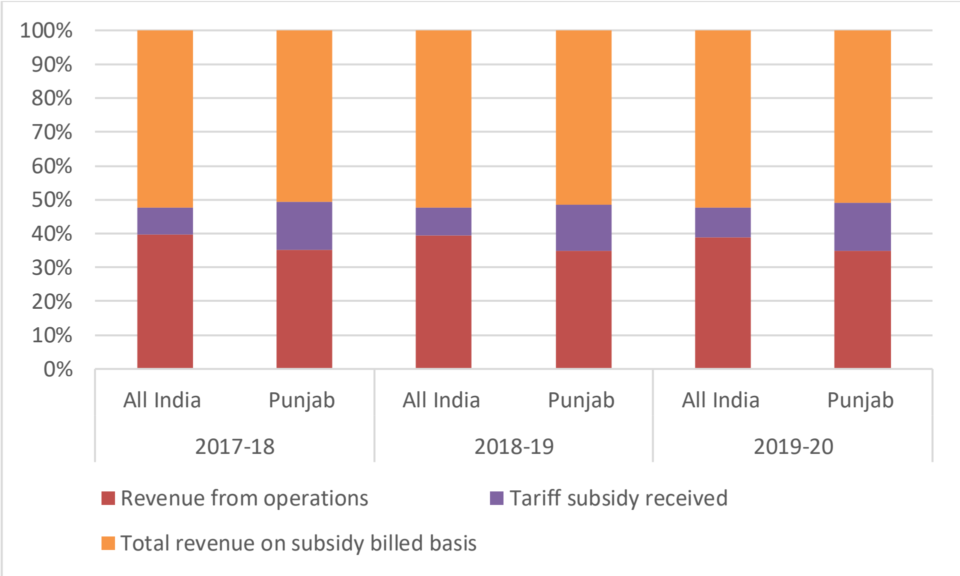
Source: Department of Finance, Punjab Government

Figure 2:4 Composition of Total Expenditure in Punjab in 2022

2.4: Impact of electricity subsidies

2.4.1: Impact on utilities

At the distribution utility's end, several issues arise due to subsidies, including leakage due to unmetered supply, and/or theft, rise in consumer size which raises subsidy burden, poor revenue generation that reduces their long-term interest, and delayed and insufficient subsidy reimbursements which affect them financially (Bhattacharya 2012). Subsidized supply severely constrains the financial viability of distribution utilities. While the tariff subsidy billed by utilities at the all-India level increased to 16.45 percent in 2019-20, the amount billed by the distribution utility in Punjab was significantly higher at 27.82 percent. This affects the financial performance of the utility. After a surplus in profit after tax on a subsidy billed basis of $34 million (Rs. 2.72 billion) in 2018-19, Punjab State Power Corporation Limited recorded a negative profit after tax of $123 million (Rs. 9.85 billion) in 2019-20 (Power Finance Corporation 2019).



Source: Performance of Distribution Utilities, PFC various years

Figure 2:5 Proportion of revenue from operations & tariff subsidy billed at India level & Punjab

Disaggregating the trends for the top-ranking states in agricultural production in 2016-17 shows that Punjab ranks poorly in recovering revenue from sales to agriculture as compared to other states.

Figure 2:6 Sales and Revenue mix in 2019 for states with high agricultural yield in 2016-17

State	Percentage sales to agriculture	Percentage revenue from agriculture	Percentage of recovery
Punjab	**23.66**	**0.00**	**0.00**
Karnataka	38.76	0.66	1.70
Bihar	3.62	3.06	84.53
Haryana	21.67	1.74	8.03
Madhya Pradesh	41.15	6.11	14.85
Maharashtra	30.34	5.58	18.39
Rajasthan	34.3	4.04	11.78
West Bengal	24.35	3.17	13.02
Andhra Pradesh	27.8	3.78	13.60
Uttar Pradesh	4.78	3.62	75.73

Source: Viswamohanan 2022

Cross subsidization: Industrial tariffs are kept high to allow for subsidized electricity supply in the agricultural and domestic sectors in India (Chattopadhyay, 2004). Industrial and commercial consumers have been charged relatively more to cross-subsidize agricultural consumers in Punjab, hitting export competitiveness and industrial production.

Figure 2:7 Category-wise break up (%) of revenue and sales in Punjab from 2015-2020

	Sales	Revenue	Sales	Revenue	Sales	Revenue	Sales	Revenue
	Agriculture		Domestic		Commercial		Industry	
2019-20	24.01	0	29.44	22.08	8.45	9.57	36.54	32.17
2018-19	23.66	0	29.85	21.60	7.35	9.39	35.74	33.80
2017-18	25.87	0	28.80	22.40	8.14	9.80	32.80	34.86
2016-17	27.14	0	29.49	23.57	8.34	10.56	30.41	36.24
2015-16	27.86	0	28.69	23.53	8.20	10.29	30.33	36.36

Source: Performance of Distribution Utilities, PFC various years

Empirical evidence indicates that distribution utilities have less incentive to provide higher quality service to communities where theft or unpaid bills are rampant, or which pay an artificially low monthly tariff. In many countries, electricity is provided to consumers at prices that do not cover the cost of generation, transmission, and distribution. Power drawn from the grid is not paid for, and is unmetered, unbilled, or pilfered (EPIC-India 2017). Losses constrain the ability of distribution utilities to provide reliable power. Poor quality discourages payment behavior, and this forms a vicious circle as the quality remains poor and power free (Blankenship et al., 2019). Subsidies reduce the incentive for firms to invest in upgrades and so make it more difficult to achieve service improvements (McRae, 2015). Low collection efficiency and high transmission & distribution losses are typically considered the biggest contributor to high aggregate technical and commercial losses (AT&C) losses. AT&C losses deteriorated for five out of the top ten ranking agriculture states, including Punjab in 2019 (Power Finance Corporation 2019).

India's electricity reform trajectory shows that the reform of the distribution utilities remains the weakest link. Most of them incur major huge losses due to expensive long-term power purchase agreements, poor infrastructure, and inefficient operations (Regy et al., 2021). There is an administration like decision-making process in state electricity boards in India that impacts efficiency (Joel 2002). Distribution utilities on average incur an average revenue loss of Rs. 0.36 for every kilowatt-hour of electricity supplied in India. The gap in recovery is attributed to non-cost reflective tariffs as well as non-technical losses due to illegal wire use, meter tempering, erroneous billing, improper recording of consumption, and nonpayment (Wong et al., 2022).

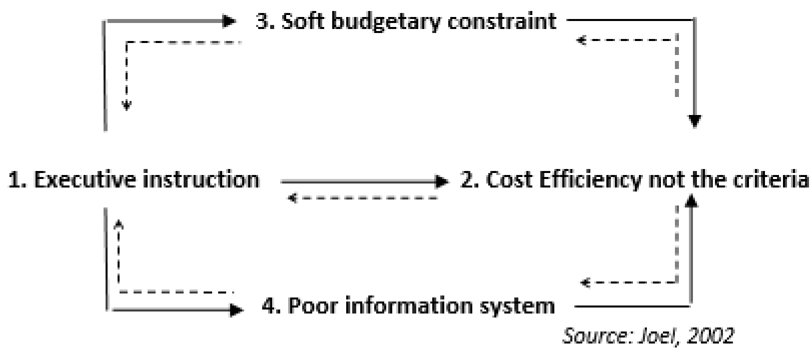


Figure 2:8 The consistency of administrative control in State Electricity Boards

The main cause of deteriorating infrastructure performance in developing economies is underinvestment due largely to the failure of governments to prescribe cost-reflective tariffs (Kessides 2005). Under the public provision, prices fall in response to public pressure, to levels that do not cover the investment cost needed to meet growing demand. Producers become reluctant to incur sunk costs they are not likely to recover. Consequently, existing infrastructure is permitted to decay, and new infrastructure does not get built (Armstrong and Sappington, 2006). On the other hand, private companies' focus on lowering costs is expected to generate a higher surplus within a competitive market structure and is considered welfare enhancing for customers (Sen et al., 2018). Incorporating the principles of fixed cost recovery in cost reflectivity is emphasized as marginal cost pricing is not enough to ensure recovery of full economic costs for a network (Pollitt 2018).

Economic theory suggests that cost-reflective prices result in net social welfare gain. However, without public interference, no automatic transfers from gainers to targeted losers will take place (Jamasb 2006). Introducing pricing without attention to distributional impacts can severely affect the reform process. Scholars have suggested the direct transfer of subsidies to farmers and letting them pay the market price of inputs (Johl et al., 2014). Farmers could be given an upfront cash transfer before each billing cycle equivalent to current subsidies, which could be used to purchase electricity priced at the socially optimum level (Mitra et al., 2022). It would be cheaper to give cash than free electricity and giving cash (or some cash equivalent or less distortionary subsidy) saves on the environmental externality. However, such a program would require large upfront cash transfers and burden the existing administrative system, which is infeasible in India (Bhattacharyya and Ganguly, 2017).

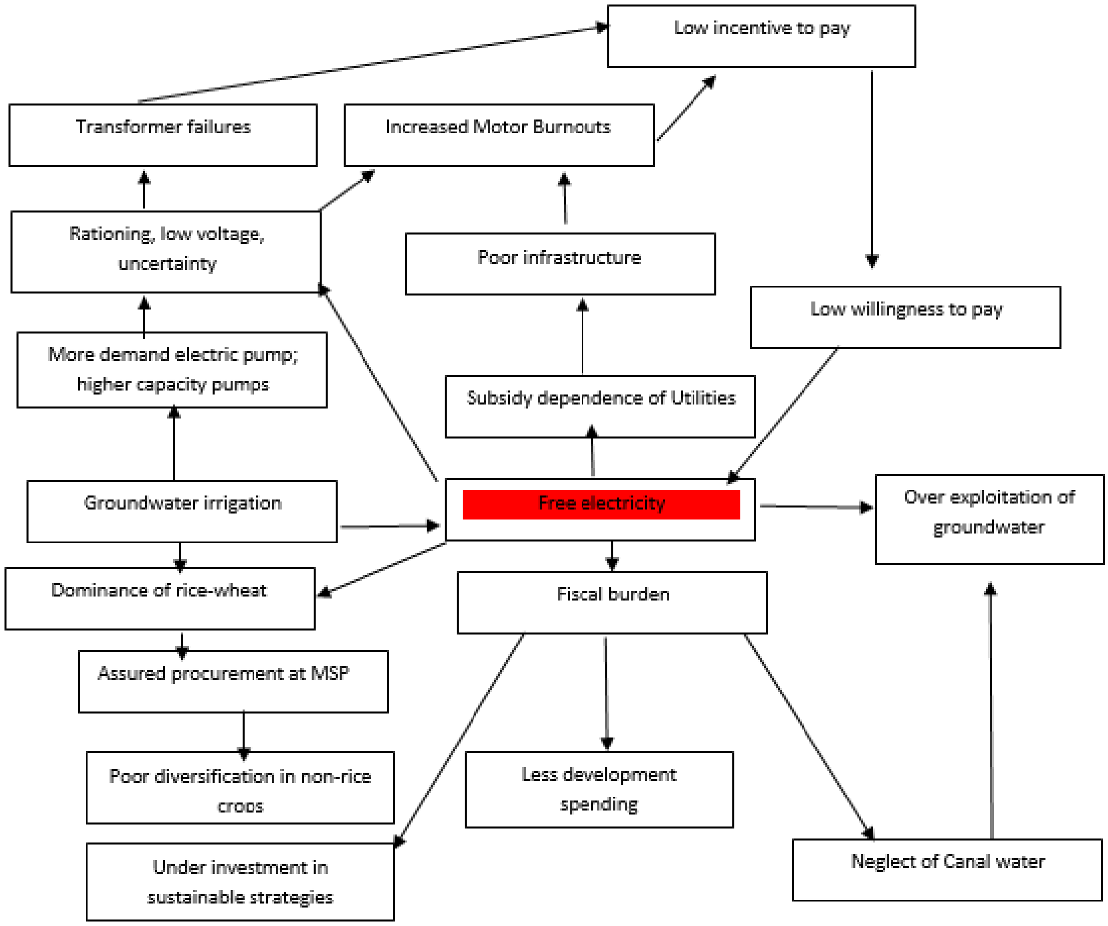
2.4.2: Impact on farmers

Fuel subsidies are inefficient as the richest households gain the most (Del Granado et al., 2012). Similarly, the distribution of electricity subsidies in Punjab is inherently regressive. There is a very wide disparity (inequality) in the distribution of relief from the electricity subsidy to different farm size groups; the large farmer got nearly 40 times what a marginal farmer got in 2010-11 (Singh 2012). 14 percent of the farmers own a 2 percent share of land and draw 1/30th of the electricity subsidy taken by 5 percent of the farmers owning 22 percent of the land. Large farmers are more likely to own more than one pump and tend to have larger pumps (Howes and Murgai, 2003). Moreover, the free supply of electricity distorts investment decisions as even marginal and small farmers invest in larger pumps than required for small holdings.

Figure 2:9 Electricity subsidy received by land-holding size

Farm size	Size (in hectare)	Operational holdings (000 hectares)	Operational area (000 hectare)	Average farm size (hectare)	Average electricity subsidy (Rs per hectare)	Electricity subsidy (Rs per farmer)
Marginal	<1	154.412	82.74	.53	11982	6350
Small	1-2	207.436	289.59	1.39	11982	16654.98
Semi-medium	2-4	367.938	1034.25	2.8	11982	33549.6
Medium	4-10	305.220	1820.28	5.96	11982	71412.72
Large	>10	57.707	910.14	15.77	11982	188956.14

Source: Author's calculations based on Singh (2012)



Source: Author's depiction based on Sarkar and Das (2014)

Figure 2:10 Flowchart depicting the energy-water nexus in agriculture

Groundwater irrigation depends on free electricity. Free electricity and assured procurement lead to rice-wheat dominance and little diversification. More demand for electric pumps and higher consumption causes falling water levels. Poor farmer lacks resources to choose alternative crops without price support. Having achieved productivity levels close to potential, farmer intensify input use to sustain current productivity levels. Unstable supply raises cost of repairing burnout motors. Farmers incur costs of digging deeper with falling water levels. Combined with declining crop returns, additional costs prompt farmers to take loans. Many of them become indebted. Poor quality disincentivizes willingness to pay for electricity.

Free electricity increases subsidy dependence of distribution utilities, disincentives investment in improvement of rural power infrastructure and leads to neglect of quality of farm power. To cope with rationing of supply and supply uncertainty, farmers tend to over apply water when supply becomes available. Unstable power causes transformer failures & motor burnouts, which contributes to low willingness to pay for electricity.

Free electricity is huge fiscal burden, crowds out other efficient expenditure and investment opportunities. Resultantly, there are lower allocations on developing water saving technologies, giving price support for other crops, improving surface irrigation, generating non-farm sector jobs etc to support the impoverished farmer in adopting sustainable agricultural practices. The result is vicious spiral of subsidized electricity, falling groundwater levels, deteriorating supply delivery, subsidy dependent electricity utilities, financing burden on governments and resistance of farmers to pricing of electricity.

Secondly, low-quality and low-cost power erodes electricity distribution systems and encourages wasteful use, even as farmers are increasingly deprived of adequate and good-quality power (Dubash 2007). Given power shortage and competing demand from different sectors, distribution utility resorts to rostering, rationing, and nighttime supply of free electricity to agriculture (Gulati and Pahuja, 2015). Low electricity prices contribute to the poor quality of electricity service (Blankenship et al., 2019) and burnout due to unbalanced supply voltage hurts the financial interests of farmers (Jairaj and Srikant, 2012). Free electricity disincentivizes the production of good quality or environment-friendly pump sets (Kannan 2013). At times, transformers fail due to overloading problems, unbalanced loading, and poor maintenance of transmission lines (Monari 2002). Instability in the supply of electricity interferes with plant growth and impacts the returns from crop production.

Unstable power supply and losses due to foregone irrigation, frequent expenditure on repairing motors and deepening wells, distorted investment decisions of getting multiple pumps and higher capacity pumps, drawing down the fragile natural resources which sustain livelihoods – exact a heavy price from an ordinary farmer, who may never have desired the free supply in the first place. Farmers continue to receive poor electricity services and may be unable or unwilling to pay for improvements; and utilities continue to stagnate in improvements in part due to the low revenues (Blankenship et al., 2019). Bad quality power feeds into farmers' unrest and translates into a refusal to pay high tariffs for low quality. The real cost of groundwater irrigation even with subsidized power is a considerable proportion of farmer costs or income at given quality levels. It is argued that farmers' decisions are logical given the context of the short time horizon and lack of credibility in the electricity reform process. Tariff increases without upfront quality improvements place a real burden on farmers (Dubash 2007). Electricity subsidies perform poorly in comparison with other potential transfer mechanisms (Komives et al., 2005).

In this context, targeting electricity subsidies is expected to improve the distribution of subsidies to the most deserving and also contain the magnitude of subsidies. Delivery of free electricity could be linked to income cum land-holding criteria. One suggested approach is to withdraw free electricity from farmers with more than 4.85 hectares of land (12 acres), who constitute about 80 percent of the beneficiaries and consume about 50 percent of the subsidy. The subsidy could be restricted to one connection per farmer. Since 17 percent of farmers own multiple connections, this could save up to 8 percent of the annual subsidy expenditure (PSCPL 2022). Punjab State Farmers and Farm Workers Commission (Punjab State Farmers & Farm Workers Commission 2018) has recommended restricting power subsidy strictly to non-income tax payee farmers and levy of a flat rate of Rs. 100/month on farmers with more than 4 hectares of land. Excluding medium and large farmers from power subsidy, who constitute about 33.2 percent of farm-households in Punjab could save $440 million (Indian Express 2020). An income cum farm-size criteria is expected to result in the automatic exclusion of farmers with multiple connections and the well-off farmers having additional income from non-agricultural sources.

2.5: Policy interventions, proposed solutions, and barriers to reform

Studies on negative externalities of electricity subsidies have focused on the damages caused to the environment, particularly over-exploitation of groundwater (Badiani and Jessoe, 2018), financial deficits of utilities leading to lower service quality (Li et al., 2018), and high opportunity cost in terms of public investments and social services (Korczyc et al., 2017), all of which hurt long-term interests of farmers and other stakeholders. Farmers are worse off with the policy of subsidized electricity as the resultant overexploitation of groundwater, under-investment in renewable and water-saving technologies and relatively unenthusiastic response to crop diversification initiatives threaten the long-term sustainability of agriculture and food security.

Various economic, administrative, technical, and institutional solutions have been suggested to address the electricity groundwater conundrum. Opportunities exist in choosing more water and energy-efficient and environment-friendly technologies to increase food production (Rasul 2016). Greater use of clean green technologies such as solar pumps could contribute to decarbonizing the electricity sector and improving environmental sustainability. With reliable and daytime solar power, solar irrigation pumps can potentially curtail the farm power subsidy burden (Shah 2018).

The state government has tried to replace inefficient policies and promote sustainable practices. Political economists suggest that the Indian state's limited ability to commit credibly to policy trajectories undermines its ability to enact and implement policy reforms (Lal 2006). Schemes implemented so far have not been able to ensure a sustainable turnaround. Some of the barriers to reform are economic considerations of the impact of changing existing unsustainable practices.

On the water conservation front, precision irrigation techniques and water-saving technologies such as direct seeding, laser leveling of fields, zero tillage, tensiometers, and delayed transplantation of rice (Sidhu et al., 2010), are being implemented, albeit with limited success. Agriculture experts advocate substituting less water-intensive crops or varieties of the same crop (Swain and Mehta, 2014, Kaur et al., 2015). However, efforts to meet crop diversification targets fall short as they compete with the policy of assured procurement of paddy, its relative higher profitability at current prices and productivity levels, and free electricity to meet the irrigation requirement at little cost. Similarly, a proposal to make investments in energy-efficient pumps to reduce energy supply at the feeder could not be implemented in Punjab (Bureau of Energy Efficiency 2010).

Economists have called for metering agricultural consumers and raising power tariffs (Kumar et al., 2011, Mukherji and Shah, 2012). It is suggested that removing energy subsidies would make farmers pump only as much as is necessary, and only for crops with high returns to water (Ray and Gul, 1999). It is estimated that a 10 percent reduction in average electricity subsidy could lead to a 6.6 percent reduction in groundwater extraction (Badiani and Jessoe, 2013). De-subsidization of energy was found to potentially save 29–82 percent of groundwater across different crops in Punjab (Srivastava et al., 2017). There is a consensus that implementing cost-reflective tariffs and proper subsidy schemes are crucial for the sustainability of resources. At the same time, protecting small and vulnerable farmers from the burden of higher tariffs is equally important. Studies acknowledge that reforming electricity pricing is a difficult political problem. Low electricity prices are a highly visible and tangible benefit to electricity consumers; removing them threatens to provoke a political backlash and social unrest (Blankenship et al., 2019). In the case of the Indian power sector, it has been suggested that major landowners, who benefit from free electricity, and labor unions have played an important role in stopping reforms (Cheng et al., 2020).

2.5.1: The adverse impact of subsidy reform

Public opposition to subsidy reform may be due to several reasons such as lack of transparency, a large reduction in scale, neglect of affordability of poor consumers, inadequate public consultation, and participation, ignoring people's reaction, lack of advanced notice, lack of credible reasons for price increases etc. (Wang and Lin, 2017). The negative impact of subsidy reform on vulnerable households can make the process politically difficult in developing countries. A study found that eliminating agricultural electricity subsidies may increase rural poverty by reducing farmers' disposable income and exacerbate food security by reducing agricultural yields (Swain and Charnoz, 2012). Bhattacharya and Ganguly (2017) found that the removal of cross-subsidies in India would increase food inflation causing a decline in household incomes, particularly in rural areas. Other studies have reported welfare losses to households with energy subsidy reform (Schaffitzel et al., 2020). A reduction in electricity subsidy is also expected to adversely impact the profitability of the paddy crop. The operational cost of tube well-irrigated rice was estimated to increase by 47 percent with a 25 percent decrease in gross margins if there was no electricity subsidy (Singh 2012). Another study estimated a decline in the net returns of crops with subsidy removal (Srivastava et al., 2017).

Figure 2:11 Number of rural, agricultural, and indebted agricultural households

State	Rural households ('00)	Agriculture households ('00)	Agriculture households as percent of rural households ('00)	Agriculture households having loan ('00)	Agricultural households indebted (%)
Punjab	27552	14083	51.1	7499	53.2

Source: Situation Assessment Survey of Agricultural households, NSSO 2013

The burden of subsidy elimination is expected to fall disproportionately more on the small and marginal farmers who comprise 32 percent of farm households in Punjab. With the highest average debt per household (Singh et al., 2008) and 53.2 percent indebted agriculture households, pricing electricity is perceived as a threat to the sustenance of rural livelihoods, particularly of the marginal farmers who are the most indebted households.

Figure 2:12 : Incidence of Indebtedness based on the size of land possessed (in percentages)

State	Marginal indebted agriculture households	Small indebted agriculture households	Semi-medium indebted agriculture households	Medium indebted agriculture households	Large indebted agriculture households
Punjab	46.2	15.9	17.9	17.6	2.4

Source: Situation Assessment Survey of Agricultural households, NSSO 2013

At the same time, fewer options for expanding cropped areas, slower growth in yields of rice and wheat, and alarming depletion and degradation of natural resources limit the range of opportunities to accelerate agricultural growth and achieve food security goals in the future. The productivity gains in the rice-wheat cropping system have slowed down, reaching a plateau. Agricultural growth in Punjab has slowed down, from five percent in the 1970s to 4.6 percent in the 1980s, 2.5 percent in the 1990s, and 1.9 percent in the 2000s. The corresponding national average was 3.2 percent in the 1990s (Deshpande and Arora, 2010).

Figure 2:13 Agricultural Growth Rate at constant prices

Decade ending	Agriculture & Livestock	Agriculture	Livestock	Primary	Secondary	Tertiary	Total
1990-91	4.497	4.035	5.848	4.644	8.708	4.964	5.384
2000-01	2.314	1.123	4.943	2.496	6.785	6.062	4.562
2004-05	2.071	1.408	3.414	2.193	4.753	6.669	4.322
2000-01 to 2004-05	1.708	1.305	2.473	1.891	4.562	6.562	4.230

Source: Deshpande & Arora, 2010

It is not difficult to understand why farmers support subsidies even though it makes the provision of reliable electricity unprofitable in the short run and leads to unsustainable use of groundwater in the medium term, thereby risking further impoverishment. As long as supply is free, farmers are not likely to give up the subsidy in favor of sustainable solutions unless and until they are not assured of better income in the immediate period and the future.

2.6: Addressing the challenge to reform with compensation as the strategy

It is suggested that solutions can emanate from an improved understanding of farmers' perspectives, negotiated compromises between various stakeholders, and a multifaceted implementation strategy combining economic, administrative, technical, and institutional solutions (Dubash 2007). Studies identifying reasons for power sector reform failure in India have found little evidence for success in accommodating farming interests. The weakness of the Indian power sector reform program is that it has not factored in mutual relationships between consumers, its claimed beneficiaries, and the politicians whose behavior it ultimately seeks to change (Lal 2006).

Practical approaches to implementing subsidy reform suggest compensating financially the social groups that would unduly suffer and actively involving all the stakeholders to make the implementation process easier (Von et al., 2004). The importance of compensating agricultural interests for their losses has been underscored by several scholars. Experts suggest compensating farmers for their losses from reform with cash transfers, or perhaps even offering temporary subsidies to encourage electricity conservation (Cheng et al., 2020). The government can set up compensatory mechanisms to mitigate at least part of the losses that some groups may suffer from subsidy cuts (IISD 2013). Compensation is a strategy that allows governments to not reduce provision but rather replace one form of provision with another form (Vidican and Loewe, 2022).

Economic theory on compensating variation suggests handing out a cash grant as compensation for the price increase due to subsidy withdrawal, in such a way that a consumer is not worse off in utility terms. It is a measure of the net revenue of a planner who must compensate the household for the energy price change after it occurs, bringing it back to its original utility level (Araghi and Barkhordari, 2012). When subsidies for a good are abandoned, the price of that good will increase, which affects consumers' utility. At the same time, the government saves the money that was being spent on the subsidies. If the savings as a result of the reform are higher than it costs to compensate consumers to bring them back to their pre-reform level of utility, then the reform is potentially a welfare gain. The compensating variation can be smaller than the savings the government has in removing subsidies (Groot and Oostveen, 2019).

The energy subsidy reform experience of several countries endorses the use of compensatory measures for sectors and segments affected by the reform. An important ingredient of successful reform is the credibility of the government to compensate vulnerable groups (Vagliasindi 2012). A common thread of reforming fuel subsidies has been the effective and visible reallocation of resources saved through removal to programs with immediate benefit to the vulnerable groups (Clements et al., 2013). These mechanisms can take the form of targeted or universal cash transfer programs, an extension of public health or education services, or increases in the minimum of average wage levels (Vidican and

Loewe, 2022).

Targeted measures or social safety nets, including direct transfers such as cash transfers and indirect transfers, are used to protect the poor. Subsidy reform was undertaken with the help of large cash compensations to assist the poor and middle class and discourage any form of social protest in Jordan and the Islamic Republic of Iran (Verme 2016). Reforms were accompanied by programs to protect the poor in Indonesia, Niger, Yemen, Mozambique, Nigeria, Mauritania, and Sudan. Mexico initiated a pilot scheme to replace electricity subsidies for the pumping of irrigation water with direct cash transfers, to remove the price distortion that had caused significant over-exploitation of groundwater (OECD 2012a). Armenia used a means-tested cash transfer program to improve collection rate and energy efficiency. The cash transfer was withdrawn in case a household over-consumed and did not pay its electricity bill. Reform initiatives are also accompanied by an expansion of social programs, sometimes in conjunction with cash transfers as compensatory measures to support subsidy reform. Another tool used by several countries to protect the low-income groups during subsidy reform is differentiated tariffs and sequenced price increases across energy products. For instance, petroleum price increases can be initially larger for products consumed more by higher-income groups and by industry. As the safety net is strengthened, subsequent rounds of reform could include larger increases in prices for fuel products that are more important in the budgets of poor households, and part of the budgetary savings can be used to finance targeted transfers to poor households (Clements et al., 2013).

The choice of the compensation program is crucial. Many governments opt for targeted transfers as they believe they cannot afford to pay benefits to all. However targeted transfer systems can be difficult to implement in low-income countries due to inclusivity and exclusivity issues, besides being perceived as paternalistic and condescending. The other alternative is to provide flat transfers to all households as was done by Iran. This would reduce the targeting costs and the possibility of manipulation, besides winning political backing for the reform process (Vidican and Loewe, 2022).

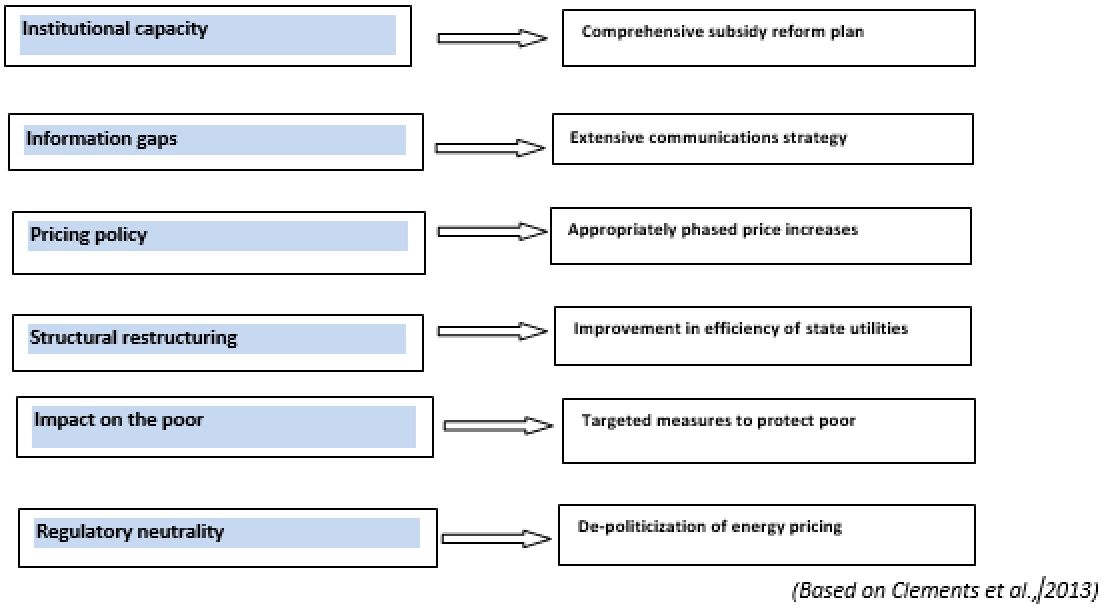


Figure 2:14 Building support for subsidy reform

Another important ingredient of successful subsidy reform is effective stakeholder consultation and communication strategy. Some governments undertaking energy subsidy reform programs either ignore communication with stakeholders or take a top-down approach that fails to account for stakeholder views and concerns. Reform proposals with a top-down approach fail to recognize that subsidy reform requires public support and change in behavior. Phasing out energy price subsidies can be politically difficult, although several countries have done so without major disruptions by building support and acceptance for reform among a variety of stakeholders. International experience shows that communication before, during, and after subsidy reform is essential to ensure the smooth rollout of a well-planned and executed energy subsidy reform program (Worley et al., 2018).

Lack of attention to building public support results in the persistence of inefficient policies and opposition to sustainable alternatives. A recent example is the lack of adequate consultation with farmers which resulted in a year-long farmers' agitation in India against the proposed reforms. The recent withdrawal of the Electricity Amendment Bill 2020 was negotiated during the yearlong farmer's agitation as it faced stiff opposition from the farming community. This rollback signals the need for introspection on the part of policymakers in India, who may just need to study the contours of farmers' opinions and attitudes before pursuing reform agenda in the future. Reducing opposition to reform and building public support thus, plays a key role in any reform effort.

It is evident that factoring in farmers' preferences and applying compensatory measures can play a crucial role in finding alternatives to electricity subsidies. These elements have far greater significance in the context of Punjab where electricity subsidies are large and have become so firmly entrenched that the fear of political backlash stalls any reform effort. Extensive debate and discussion about encouraging the sustainable use of resources, implementing crop diversification, enforcing metering, and changing the energy mix turn on the question of how to bring about these changes in the current subsidy regime. There are no easy answers as the role of farmers' preferences and compensation measures are understudied in the context of Punjab. To close this information gap and help in understanding the acceptability and preferences of farmers to reform proposals, this research has conducted a representative survey of farmers across twenty districts of Punjab. The study applied discrete choice experiments to examine preferences for economic incentives designed to induce energy-saving behavior among farmers in Punjab. Understanding and determining the heterogeneity of farmers' response behavior, preferences, and acceptance of conservation strategies supported by compensatory measures can enhance the effectiveness of these policy changes. The focus of this work is studying three specific areas of reform – inducing substitution of water-intensive varieties by low-water rice varieties, motivating change to metered consumption, and encouraging the adoption of solar irrigation pumps.

2.7: Discrete Choice Experiment approach

The discrete choice experiment method is chosen as the methodology for the three chapters. It is considered an appropriate method to elicit preferences, choice probabilities, and willingness to pay (Sagebiel and Rommel, 2014). Choice models assume that individuals' preferences are stated through their choices. Ideally, a choice experiment has more than two alternatives, a large number of attributes describing each alternative, and characteristics describing the socio-economic profile of each sampled respondent. Respondents are repeatedly asked to choose between alternatives that include these attributes with associated attribute levels. It is assumed that an individual would choose an alternative in a given choice set if the utility derived from that alternative is greater than from any other offered alternative. This allows the estimation of marginal utilities and provides rich data for economic evaluation and decision-making.

2.7.1: Relevance of choice experiment

Theoretical models and simulation approaches have analyzed the interconnectedness between groundwater use and energy prices. Zilberman et al., (2008) developed theoretical models to analyze the effects of rising energy prices on the economics of water in agriculture and found that the higher cost of energy substantially increases the cost of groundwater. Zhu et al. (2013) simulated the effects of energy prices on groundwater extraction in India, China, the U.S., and Vietnam. Kumar (2005) presented a theoretical model to analyze farmers' response to changes in power tariff and water allocation regimes vis-a-vis energy and groundwater use. The analysis shows that unit pricing of electricity influences groundwater use efficiency and productivity positively.

In the U.S. context, Hendricks and Peterson (2012) estimated irrigation water demand in Kansas using an estimate of extraction cost as their proxy for water price. With a focus on the effects of energy prices on water demand and crop choices, Pfeiffer and Lin (2014) used an econometric model of a farmer's irrigation water pumping decision with two components: the intensive margin which estimates the farmer's water demand conditional on his crop acreage allocation decisions and the extensive margin, which estimates the farmer's choice of how many acres to allocate to each crop using a simultaneous equations selection model. They found that increasing energy prices affect crop selection decisions, crop acreage allocation decisions, and the demand for water by farmers. The model examines how changes in energy prices affect not only water demand conditional on crop choice, but also crop choice and crop acreage allocation decisions as well.

Wang et al., (2015) used a theoretical model to analyze the effectiveness of different policy alternatives in incentivizing individual farmer to actually save water. They examined farmer's incentive-driven responses to policy tools, including (1) irrigation technology subsidy, (2) increased water cost, (3) unit subsidies for water saving, and (4) subsidies on water-conservative crop. They found that the response to water conservation policies varies with the region. In regions where groundwater already poses a constraint, the unit subsidy for actual water saved and price subsidy for water-conservative crops are more effective in achieving the water conservation goal.

Some studies have used interviews or survey data to analyze the relationship between energy and groundwater extraction in India (Scott and Shah, 2004). In a developing country context, Badiani and Jessoe (2013) empirically analyzed the impact of electricity subsidies on groundwater extraction and agricultural production in India. They observed that integrated regulatory mechanisms, public participation and energy supply and pricing policies are cornerstones of sustainable groundwater management in developing countries. The literature also includes game theoretic approaches in which players take into consideration groundwater extraction externalities to reduce over-exploitation. Algorithms have been developed to help well users to change their pumping schedules such that farmers pump alternatively, in a way that Nash equilibrium is reached (Nagkoulis and Katsifarakis, 2022).

In explaining and predicting energy related individual behavior, traditional economic models postulate that people make decisions that yield the optimal result given budget constraints, and that behavioural choices can be improved by providing people with more information and more options. In stark contrast to such assumptions, a growing body of scientific research demonstrates that consumer behaviour can deviate systematically from neoclassical economic assumptions of rationality due to certain fundamental and persistent biases, including status quo bias, loss and risk aversion, sunk-cost effects, temporal and spatial discounting, and the availability bias. Hence key insights from behavioural economics and psychology can guide the effective design and delivery of consumer-focused strategies and public policy interventions to improve energy conservation, particularly solutions that capitalize on message framing, choice architecture and incentivization to shift human behaviour (Frederiks et al., 2015).

Most economic models developed to predict farmers' response patterns simplify the decision by specifying an objective function or decision problem and adding assumptions and imposing constraints to deal with further complexities (Murray and Wright, 2001). Farmers’ responses to various policy instruments are then modeled in mathematical programming, mathematical simulation, or an econometric framework. However, incorrect specification of the basic objective function, assumption, or constraint is a major problem in microeconomic modeling. At times, a small change in specification can drastically alter the results (Just 1993). Conducting field experiments is costly as a large number of experimental treatments are required to evaluate changes in attributes.

The quantitative ranking or qualitative methods to study farmers’ preferences are of limited use as they cannot identify the relative weight of the factors driving farmers’ decisions or estimate trade-offs between alternative options. In contrast, choice experiments are easier to implement and have been used in recent studies to estimate farmers’ decision-making behavior. Choice experiments enable an assessment of an individual’s willingness to adopt a certain policy instrument or innovation. This type of information cannot be obtained from ordinary qualitative or quantitative surveys when new policies are being implemented, since such data does not exist. Choice experimentation is considered a robust ex-ante alternative that allows respondents to hypothetically consider various options and provides information on decision-making based on their perceived utility and costs (Aravindakshan et al., 2021). Discrete choice methods provide quantitative information on the strength of preferences and prediction of the likely take-up of defined options. The real value of choice experiments is in helping 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 trade-offs allows policymakers to estimate how much of one attribute a consumer would be willing to give up for improvement in another.

The second advantage of the discrete choice method is that it is survey-based i.e., the method relies upon what respondents say they will do - also referred to as stated preference data, rather than what they do - referred to as revealed preference data. The literature shows a healthy skepticism towards relying on stated preference data compared to revealed preference data, but there are good reasons for researchers' interest in stated preference data (Ryan et al. 2012). A key advantage of this hypothetical approach is that it allows preferences to be elicited for options that do not exist. It is useful to contrast discrete choice methods with randomized experiments in public policy, which are another way of eliciting revealed preferences. Randomized experiments are constrained by the range of opportunities available. While a discrete choice method commonly 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 methods also allows the independent variables to be identified in advance, which allows the identification of all variables of interest. This contrasts with revealed preference data, which cannot be controlled a-priori so model identification cannot be guaranteed as multi-collinearity may be present. Moreover, the use of revealed preference data is limited in most developing countries given the lack of data. A third factor is the cost-stated preference method allows large quantities of data to be collected at a moderate cost. A discrete choice experiment can be conducted as a prelude to a randomized experiment, which is more costly.

Early empirical applications of choice experiments were in the disciplines of marketing and health before its extension to the environment, tourism, cultural heritage, noise pollution, forests, water resources, and food labeling. Its use has grown in environmental and public economics research in recent years to inform the design of environmental policies and projects (Beharry-Borg et al., 2013; Broch and Vedal, 2012; Espinosa Goded et al., 2010; Greiner, 2015; Hanley et al., 2007). The emphasis of social scientists has been on investigating the adoption of sustainable management practices and ex-ante agricultural technology adoption (Mahadevan and Asafu-Adjaye, 2015; Lambrecht et al., 2015; Tesfaye et al 2019).

2.7.2: Theoretical framework

The choice experiment approach is rooted in the random utility framework introduced by Louviere and Woodworth (1983). It draws upon Lancaster's economic theory of value (Lancaster 1966), which assumes that utility is derived from the characteristics of a good; and that individuals are utility-maximizing agents who are willing to trade-off between attributes in the choice experiment. The random utility model provides the theoretical underpinning for the analysis of the discrete choice data. In this framework individual n is assumed to choose between J alternatives, opting for the one associated with the highest utility (benefit or satisfaction). Thus, individual n will choose i over j if and only if

$$U_{ni} > U_{nj} \quad ¥i \neq j \qquad (2.1)$$

where U is the utility.

The model assumes that the utility (U) associated with a particular choice is made up of two components. The deterministic component V_{ni} is a function of m attributes (x_1,…, x_m), which are observed, and the random component, ε_n , which is a function of unobserved attributes and individual-level variation in tastes (Louviere et al., 2000). The utility, U, to individual n associated with i can be specified as:

$$U_n = V_n + \in_n \quad (2.2)$$

$$U_n = \alpha_1 + \beta_1 x_{1n} + \beta_2 x_{2n} + \cdots .. + \beta_m x_{1mn} + \in_n \quad (2.3)$$

where the betas, ß, provide quantitative information on the strength of preference for each attribute level, as well as trade-offs, monetary values, and predicted take-up of the option.

However, the utility of any given option is not directly observable, and therefore the coefficients in equation (2.2) cannot be estimated directly. The DCE data are therefore modeled within a probabilistic framework. That is, when individual n is presented with a pair of alternatives, the probability (P) individual n chooses i over j can be estimated as

$$P_{nj} = P_r[U_{ni} > U_{nj}] \quad ¥ i \neq j \quad (2.4)$$

Using equation (2.2) this becomes

$$P_n = P_r[\in_{ni} - \in_{nj} < V_{ni} - V_{nj}] \quad ¥\mathrm{i} \neq \mathrm{j} \quad (2.5)$$

To estimate equation (2.2) an assumption is made about the distribution of the error term using the logit model. Using the logit model, the probability of choosing i is defined as:

$$Pi = \frac{\exp(Vi)}{\sum_{j=1}^{n}(\exp(\mathrm{Vj})} \quad (2.6)$$

2.8: Materials and Methods

2.8.1: Development of Questionnaire

As the first step in designing the survey questionnaire, scoping trips to Patiala, Jalandhar, Sangrur, Mansa, and Bhatinda districts were undertaken to meet with state officials and farmers. 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. In addition, interviews were conducted with senior officials of Punjab State Electricity Regulatory Commission, Agriculture Supply Management and Commercial divisions of Punjab State Power Corporation, Punjab Energy Development Agency, and officials of Departments 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 belonging to Punjab Agriculture University, government officials in relevant Ministries, and research bodies.

Farmers' feedback received during the interactions and visits to electric feeders in rural areas helped finalize the questionnaire. Interviews were also held with small & marginal farmers as well as medium & large farmers to understand the electricity situation in rural Punjab, existing levels of electricity supply, problems faced due to uncertain supply and nighttime supply, power theft, political and cultural factors, and approximate level of tariff farmers may be willing to pay for better quality supply. About eight to ten people took part in each discussion. These scoping visits gave guidance about designing the incentive levels and electricity tariff rates and formed the basis of drafting the questionnaire, the attributes, and the levels. A preliminary set of attributes and levels were piloted for further refinement.

After the finalization of the attributes and levels, the choice set was generated with the help of Ngene software (Ngene 2021). Since the full-factorial design is demanding on the respondents, a fractional factorial design was generated. The questionnaire was tested via personal interviews and after observing the responses and feedback, the main survey was conducted. The in-person interview mode of survey administration was chosen. To minimize interviewer bias, the author administered the main survey questions.

2.8.2: Elicitation of preferences

Care was taken in seeking answers to discrete choice questions. First, the attributes and the associated levels were clearly articulated. 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 the 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 incentive and subsidy schemes in Punjab helped overcome this challenge.

2.8.3: Survey Administration

The data was collected through interviews 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 survey was carried out from August to November 2021 and in March 2022. The survey was conducted with the help of a questionnaire and prior verbal consent of respondents was obtained. A detailed explanatory handout was read out to the respondents describing the study and its purpose. Participation was voluntary, and assurance of confidentiality was given to the respondents.

2.8.4: Sampling procedure

A stratified random sampling method was used to choose a representative sample from the study area. Punjab has 23 districts and three agro-climatic zones have been demarcated in Punjab based on cropping pattern, rainfall, soil texture, soil quality, underground water, temperature, and humidity - I: Sub-mountainous Zone; II: Central Zone, and III: South-western Zone. In the first stage of the geographical selection, twenty districts that account for the major share of electricity consumption were selected. All districts in the three zones were covered in the survey except for one district in each zone. Secondary data including the number of villages and the number of farmer consumers from each of the twenty districts were collected. Three-four blocks were randomly chosen, and, on average, 4-5 villages representative of the district were randomly chosen using random number tables. Basic information such as the number of farmers, land use, crops cultivated, source of irrigation, power supply schedules, etc. was collected. Farmers were selected by dividing the village into three or four segments and then households were selected randomly from each segment to meet the target sample size, keeping care that a minimum number of farmers belonging to different land size groups were included in the survey. The landholding size used for stratification included marginal (<1ha of land), small (1-2ha), semi-medium (2-4ha), medium (4-10ha), and large (>10ha) farmers. The stratification by land size was undertaken to examine the effect of socio-economic and demographic characteristics on preference heterogeneities.

2.8.5: Structure of Questionnaire

The first section of the questionnaire collected administrative information such as identification of farmer, informed consent, survey dates, age, sex, education, income-earning source, land holding size, cropping pattern, sources of irrigation, number, and power of tube wells, and dependence on diesel for paddy crop. Farmers answered questions about their demographic, financial, and socioeconomic characteristics as well as the crops raised on their farms, and the frequency of irrigating their fields.

The second section confronted farmers with discrete choice questions. The third section aimed to uncover farmers' attitudes and opinions about groundwater depletion, water conservation, withdrawal of free farm power, access to electricity, level of satisfaction with the power supply, willingness to pay for metered supply or flat rate tariff, direct benefit transfer of farm subsidy, targeted delivery of subsidy, pre-paid meters, perceived benefits of increased hours of supply and lower outages, incentives for crop diversification, benefits from subsidies, renewable energy, reforms in the energy sector, etc. Respondents were asked a variety of questions about their electricity usage and their preferences and opinions toward electricity supply and willingness to pay. Additionally, questions were asked about whether the electricity revenues should be directed towards essential repair and up-gradation of the electricity infrastructure and other welfare-enhancing activities.

2.9: Results of the survey – Socio-Demographics

The descriptive statistics for the sample of 859 respondents summarize the data and assist in understanding how the sample is distributed across age, education, and ownership of assets. The histograms depict the number of farmers in each class.

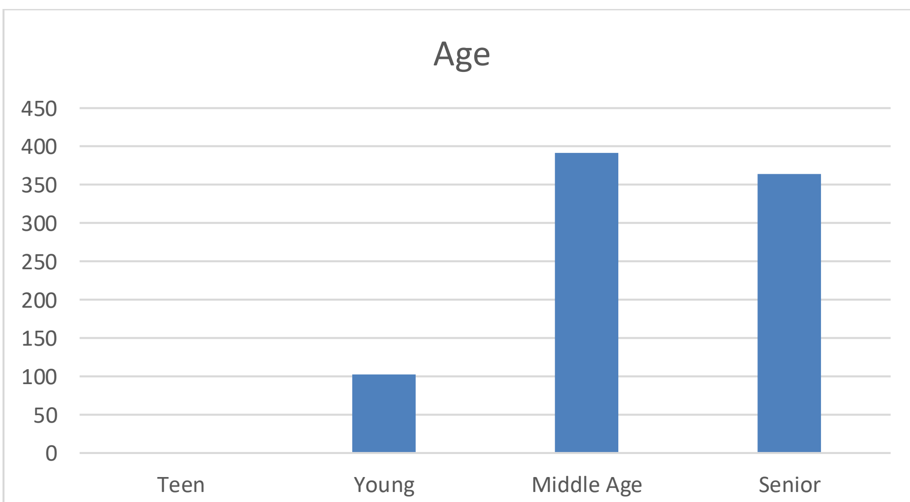


Figure 2:15 Histogram of age groups of sampled farmers

Young farmers below 30 years constituted 12 percent, middle-aged farmers between 31-50 years constituted 46 percent and senior farmers above the age of 51 years constituted 42 percent of the respondents. The age group histogram is depicted in figure 2.15.

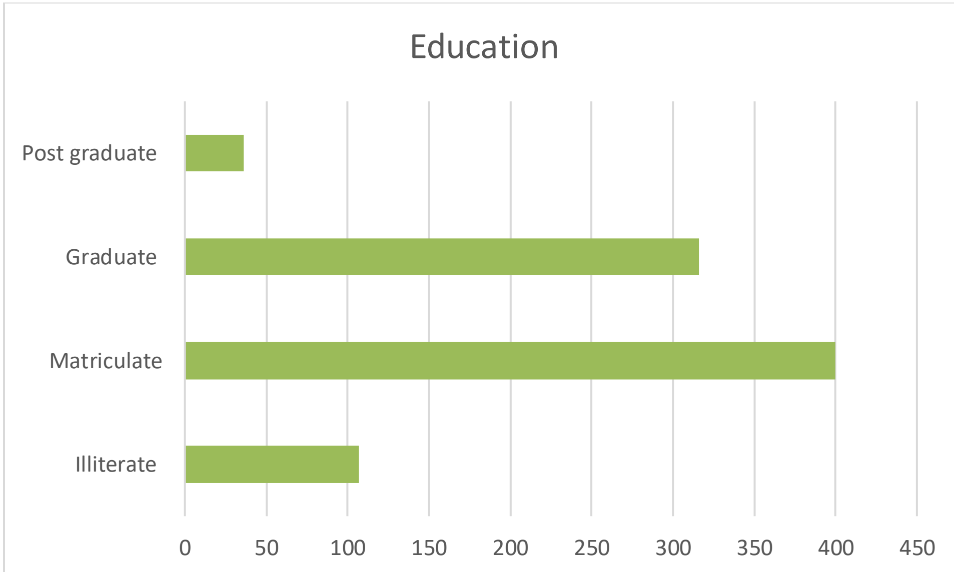


Figure 2:16 Histogram of educational qualifications of sampled farmers

About 46 percent of the farmers were matriculates, 36 percent were graduates, and 4 percent had postgraduate qualifications. Figure 2.16 depicts the histogram of the education level of the farmers.

Based on the total operational land holdings, 12 percent had less than 1 hectare of land, 21.88 percent had 1-2 hectares, 25.49 percent had 2-4 hectares, 22 percent had 4-10 hectares and 9.54 percent of the farmers had more than 10 hectares of land. Figure 2.17 shows the histogram of the distribution of holdings among the respondent farmers.

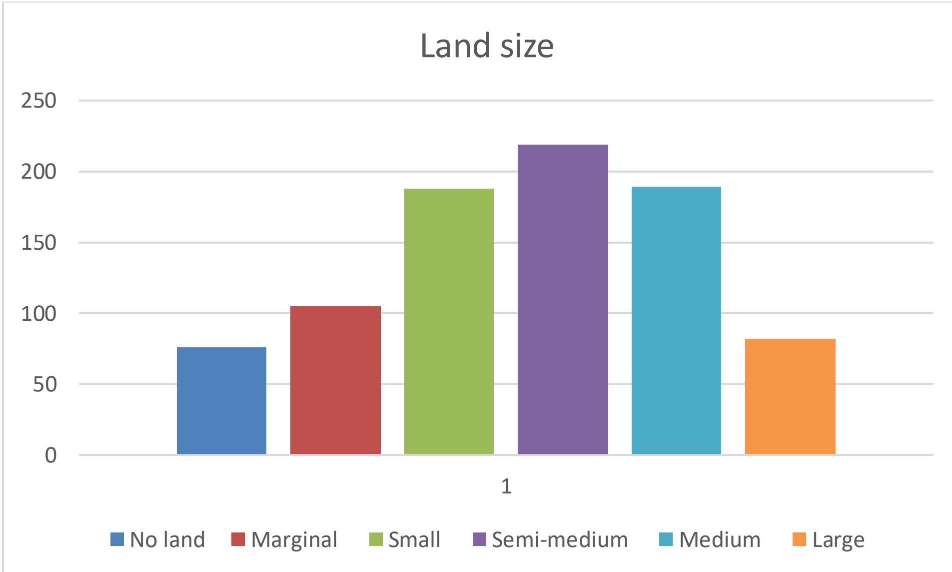


Figure 2:17 : Histogram of land size of sampled farmers

The histogram on the distribution of sanctioned load among the sample farmers shown in figure 2.18 indicates the existence of higher capacity pumps and multiple connections. 51 percent of the farmers had connected load up to 15 HP, around 29 percent had 15-50 HP load and 6 percent had more than 50 HP load.

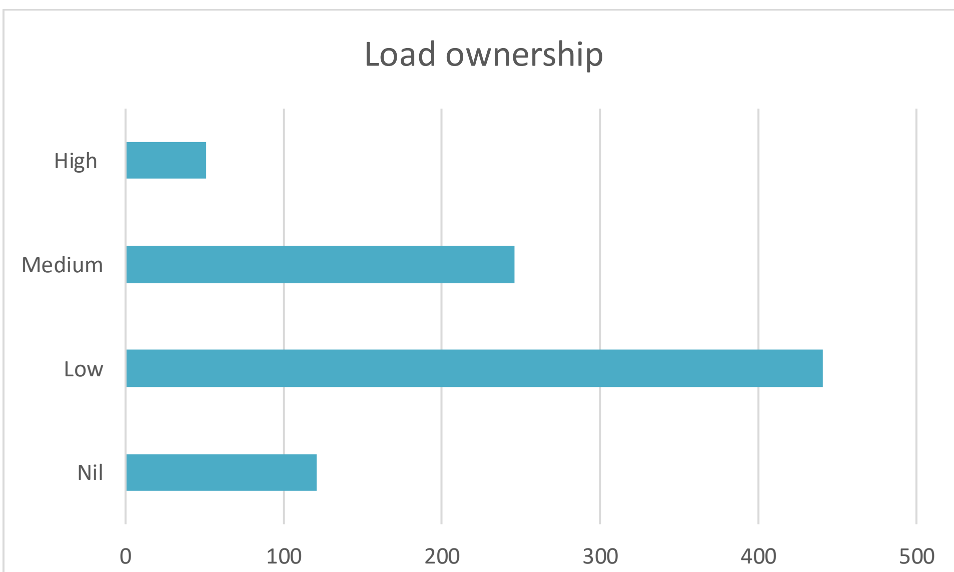


Figure 2:18 Histogram of distribution of sanctioned load among sampled farmers

A pie chart in figure 2.19 shows the distribution of electric tube wells among the sampled farmers. Multiple tube well-owning farmers were more than single tube well-owning farmers.

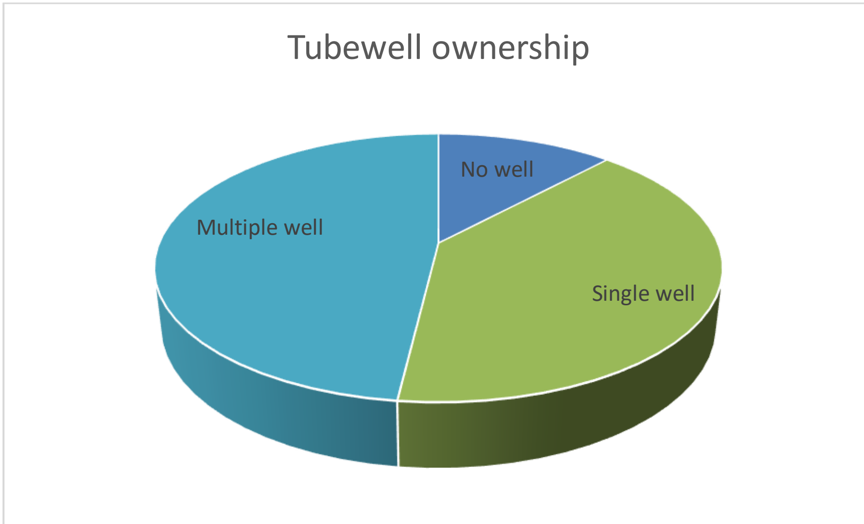


Figure 2:19 Pie diagram of the ownership of electric tube wells among sampled farmers

2.10: Conclusion

Several solutions have been advocated for reforming electricity subsidies and saving groundwater through crop diversification, electricity pricing, and exploiting renewable energy with potential benefits of reducing pressure on budgets, improving energy access, encouraging low-carbon energy, and arresting rapid depletion of natural resources, particularly groundwater. However, paying more attention to understanding the motivations and drivers for farmers' action and response behavior is urgently required, as highlighted in the preceding paragraphs. Behavioral factors have a significant influence on the outcome of policy instruments in that they can either complement or constrain the effects of policies (OECD 2012b). Therefore, a critical understanding of the drivers of farmers' acceptability and response behavior to proposed conservation strategies is of crucial importance. Integrating environmental considerations in the pricing and use of water and electricity can be achieved by factoring in the concerns and perceptions of the stakeholders, primarily the farmers, and proactively addressing those concerns.

The focus of this study is on analyzing farmers' acceptability to changes in primarily three specific study areas, adopting low-water rice varieties, metered consumption, and solar irrigation pumps with the help of economic incentives and reducing electricity subsidies. The decision-making framework urgently needs a paradigm shift that recognizes cross-sectoral externalities, explores feasible trade-offs, and helps policymakers achieve greater policy coherence, among the three sectors, which is critical for moving towards more efficient, equitable, and sustainable use of resources. It is hoped that this study contributes to a healthy discussion and better understanding of the challenges for evolving sustainable solutions among researchers and policymakers in the electricity, water, and agriculture sectors.

The application of stated preference method by the author in this study would provide policy makers with information on farmers' preferences for interventions that is intended to influence their choices aimed at encouraging energy and water conservation and motivating pro-environment behaviour. Further insights can be achieved by conducting more rigorous scientific research—namely, randomized controlled trials with larger samples of participants, more objective measures of actual behaviour, and longitudinal data collected over extended timeframes.

References

Araghi, M. K., & Barkhordari, S. (2012). An evaluation of the welfare effects of reducing energy subsidies in Iran. Energy Policy, 47, 398-404.

Armstrong, M., & Sappington, D.E. (2006). Regulation, competition, and liberalization. Journal of Economic Literature, 44(2), 325-366.

Aravindakshan, S., Krupnik, T. J., Amjath-Babu, T. S., Speelman, S., Tur-Cardona, J., Tittonell, P., & Groot, J. C. (2021). Quantifying farmers' preferences for cropping systems intensification: A choice experiment approach applied in coastal Bangladesh's risk prone farming systems. Agricultural Systems, 189, 103069, 1-14.

Badiani, R., & Jessoe, K. (2013). The impact of electricity subsidies on groundwater extraction and agricultural production. Department of Agriculture and Resource Economics Working Paper, University of California Davis.

Badiani-Magnusson, R., & Jessoe, K. (2018). Electricity prices, groundwater, and agriculture: the environmental and agricultural impacts of electricity subsidies in India. In agricultural productivity and producer behavior (pp. 157-183). University of Chicago Press, 157-183.

Beharry-Borg, N., Smart, J. C., Termansen, M., & Hubacek, K. (2013). Evaluating farmers' likely participation in a payment program for water quality protection in the UK uplands. Regional Environmental Change, 13(3), 633-647.

Bhattacharyya, R., & Ganguly, A. (2017). Cross subsidy removal in electricity pricing in India. Energy Policy, 100, 181-190.

Bhattacharyya, S. C. (2012). Energy access programmes and sustainable development: A critical review and analysis. Energy for Sustainable Development, 16(3), 260-271.

Birner, R., Gupta, S., Sharma, N., & Palaniswamy, N. (2007). The political economy of agricultural policy reform in India: The case of fertilizer supply and electricity supply for groundwater irrigation. New Delhi, India: IFPRI.

Blankenship, B., Wong, J. C. Y., & Urpelainen, J. (2019). Explaining willingness to pay for pricing reforms that improve electricity service in India. Energy Policy, 128, 459-469.

Broch, S. W., & Vedel, S. E. (2012). Using choice experiments to investigate the policy relevance of heterogeneity in farmer agri-environmental contract preferences. Environmental and Resource Economics, 51(4), 561-581.

Bureau of Energy Efficiency 2010) Pilot Agricultural Demand Side Management (Ag- DSM) Project at Muktsar & Taran Taran, Punjab Detailed Project Report.

Chattopadhyay, P. (2004). Cross-subsidy in electricity tariffs: evidence from India. Energy Policy, 32(5), 673-684.

Cheng, C. Y., Lee, Y. J., Murray, G., Noh, Y., Urpelainen, J., & Van Horn, J. (2020). Vested interests: Examining the political obstacles to power sector reform in twenty Indian states. Energy Research & Social Science, 70, 101766, 1-12.

Clements, M. B. J., Coady, D., Fabrizio, M. S., Gupta, M. S., Alleyne, M. T. S. C., & Sdralevich, M. C. A. (2013). Energy subsidy reform: lessons and implications. International Monetary Fund.

Del Granado, F. J. A., Coady, D., & Gillingham, R. (2012). The unequal benefits of fuel subsidies: A review of evidence for developing countries. World Development, 40(11), 2234-2248.

Department of Finance, (2020), Fiscal profile, Government of Punjab https://finance.punjab.gov.in/Singleton/FiscalProfile.

Deshpande, R. S., & Arora, S. (Eds.). (2010). Agrarian crisis and farmer suicides (Vol. 12). SAGE Publications Ltd.

Dubash, N. K. (2007). The electricity-groundwater conundrum: Case for a political solution to a political problem. Economic and Political Weekly, 45-55.

EPIC-India, (2017). Increasing Energy Access by Reducing Electricity Distribution Losses. Energy Policy Institute at the University of Chicago, ⟨https://epic.uchicago.in/project/increasing-energy-access-by-reducing-electricity-distribution-losses⟩.

EPW Time Series data (2020). Per capita User Group-wise consumption, EPW Research Foundation, Mumbai.

Espinosa-Goded, M., Barreiro-Hurlé, J., & Ruto, E. (2010). What do farmers want from agri-environmental scheme design? A choice experiment approach. Journal of Agricultural Economics, 61(2), 259-273.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews, 41, 1385-1394.

Golden, M. A., & Min, B. (2012). Theft and loss of electricity in an Indian state. Working Paper 12/0060, International Growth Centre, 1-36.

Greiner, R. (2015). Motivations and attitudes influence farmers' willingness to participate in biodiversity conservation contracts. Agricultural Systems, 137, 154-165.

Groot, L., & Oostveen, T. (2019). Welfare effects of energy subsidy reform in developing countries. Review of Development Economics, 23(4), 1926-1944.

Gulati, M., & Pahuja, S. (2015). Direct delivery of power subsidy to manage energy–groundwater–agriculture nexus. Aquatic Procedia, 5, 22-30.

Haldea, G. (2001). Whither electricity reforms?. Economic and Political Weekly, 1389-1391.

Hanley, N., Wright, R. E., & Alvarez-Farizo, B. (2007). Estimating the economic value of improvements in river ecology using choice experiments: an application to the water framework directive. In Environmental value transfer: Issues and methods (pp. 111-130). Springer, Dordrecht.

Hardin, G. (1968). The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality. Science, 162(3859), 1243-1248.

Howes, S., & Murgai, R. (2003). Incidence of agricultural power subsidies: An estimate. Economic and Political Weekly, 1533-1535.
Indian Express (2020). Punjab farm power subsidy benefits big farmers more than small ones
https://indianexpress.com/article/india/punjab-farm-power-subsidy-benefits-big-farmers-more-than-the-small-ones-6558808/, 17.08.20.
IISD (2013). A Guidebook to Fossil-Fuel Subsidy Reform for Policy-Makers in South-East Asia; International Institute for Sustainable Development: Geneva, 2013.
Jairaj, K. S., & Srikant, K. (2012). Simulation and testing of induction motors used with irrigation pumps. International Journal of Automation and Power Engineering, 1(2), 23-28.
Jamasb, T. (2006). Between the state and market: Electricity sector reform in developing countries. Utilities Policy, 14(1), 14-30.
Joël, R. U. E. T. (2002). The State Electricity Boards: Private Vs. Public Enterprisation. Indian Journal of Public Administration, 48(1), 1-24.
Johl, S. S., Sidhu, R. S., & Vatta, K. (2014). Natural Resources Management in Punjab Agriculture: Challenges and Way Forward. Discussion Paper Centers for International Project Trust, New Delhi.
Just, R. E. (1993). Discovering production and supply relationships: present status and future opportunities. Review of Marketing and Agricultural Economics, 61(430-2016-31665), 11-40.
Kannan, E. (2013). Do farmers need free electricity? Implications for groundwater use in south India. Journal of Social and Economic Development, 15(2), 16-28.
Kaur, B., Vatta, K., & Sidhu, R. S. (2015). Optimizing irrigation water use in Punjab agriculture: Role of crop diversification and technology. Indian Journal of Agricultural Economics, 70(3), 307-318.
Kessides, I. N. (2005). Infrastructure privatization and regulation: Promises and perils. The World Bank Research Observer, 20(1), 81-108.
Komives, K., Foster, V., Halpern, J., & Wodon, Q. (2005). Water, electricity, and the poor: Who benefits from utility subsidies? World Bank Publications.
Koplow, D. (2004). Subsidies to energy industries. Encyclopedia of Energy, 5(1), 749-764.
Korczyc, E., Oré, M. A. H., Olivera, L., & Rizo, L. (2017). The Fiscal Impact of Electricity Subsidies in Central America. Fiscal and Welfare Impacts of Electricity Subsidies in Central America.
Kumar, M. D., Scott, C. A., & Singh, O. P. (2011). Inducing the shift from flat-rate or free agricultural power to metered supply: Implications for groundwater depletion and power sector viability in India. Journal of Hydrology, 409(1-2), 382-394.
Kumar, M. D. (2005). Impact of electricity prices and volumetric water allocation on energy and groundwater demand management: analysis from Western India. Energy policy, 33(1), 39-51.
Kumar, R. R., Jha, G. K., & Velayudhan, P. K. (2022). Linkage of Electricity with Agricultural

Growth and Technology Factors: An Illustration of India's Case. Energies, 15(7), 2422, 1-14.

Lal, S. (2006). Can good economics ever be good politics?: case study of the power sector in India (No. 83). World Bank Publications.

Lambrecht, I., Vranken, L., Merckx, R., Vanlauwe, B., & Maertens, M. (2015). Ex ante appraisal of agricultural research and extension: a choice experiment on climbing beans in Burundi. Outlook on Agriculture, 44(1), 61-67.

Li, F., Wang, W., & Yi, Z. (2018). Cross-subsidies and government transfers: Impacts on electricity service quality in Colombia. Sustainability, 10(5), 1599, 2-15.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: analysis and applications. Cambridge University Press.

Mahadevan, R., & Asafu-Adjaye, J. (2015). Exploring the potential for green revolution: a choice experiment on maize farmers in Northern Ghana. African Journal of Agricultural and Resource Economics, 10(311-2016-5637), 207-221.

McClelland, L., & Cook, S. W. (1980). Promoting Energy Conservation in Master-Metered Apartments through Group Financial Incentives 1. Journal of Applied Social Psychology, 10(1), 20-31.

McRae, S. (2015). Infrastructure quality and the subsidy trap. American Economic Review, 105(1), 35-66.

Mitra, A., Balasubramanya, S., & Brouwer, R. (2022). Can cash incentives modify groundwater pumping behaviors? Evidence from an experiment in Punjab. American Journal of Agricultural Economics, 1-27.

Monari, L., & Mostefai, D. (2001). India: Power supply to agriculture summary report. Energy Sector Unit, South Asia Regional Office. New Delhi: World Bank.

Monari, L. (2002). Power subsidies: A reality check on subsidizing power for irrigation in India. Public Policy for the Private Sector Note 244. Washington, D.C.: World Bank.

Mukherji, A., & Shah, T. (2012). A review of international experience in managing energy irrigation nexus, International Water Management Institute Water Policy Research Highlight, 1-6.

Murray-Prior, R. B., & Wright, V. E. (2001). Influence of strategies and heuristics on farmers' response to change under uncertainty. Australian Journal of Agricultural and Resource Economics, 45(4), 573-598.

Nagkoulis, N., & Katsifarakis, K. L. (2022). Using game theory to assign groundwater pumping schedules. Water Resources Management, 36(5), 1571-1586.

Ngene, C. (2021). 1.3 User Manual & Reference Guide. Choice Metrics Pty Ltd, Sydney, Australia.

NSSO (2013). Situation Assessment Survey of Agriculture Households, National Sample Survey Organization, Ministry of Statistics and Program Implementation, Government of India.

OECD (2012a). An OECD-Wide Inventory of Support to Fossil-Fuel Production or Use, OECD Publishing Paris, 1-8.

OECD (2012b). Farmer Behaviour, Agricultural Management and Climate Change., OECD Publishing Paris, https://doi.org/10.1787/9789264167650-en.

Petersen, J. E., Shunturov, V., Janda, K., Platt, G., & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. International Journal of Sustainability in Higher Education. 16-33.

Pfeiffer, L., & Lin, C. Y. C. (2014). The effects of energy prices on agricultural groundwater extraction from the High Plains Aquifer. American Journal of Agricultural Economics, 96(5), 1349-1362.

Power Finance Corporation Limited (2019), The Performance of State Power Utilities for the years, New Delhi.

Pollitt, M. G. (2018). Electricity Network Charging in the Presence of Distributed Energy Resources. Economics of Energy & Environmental Policy, 7(1), 89-104.

Punjab State Farmers & Farm Workers Commission (2018), Punjab State Farmers Policy, Punjab State Farmers & Farm Workers Commission, Chandigarh.

Punjab State Electricity Regulatory Commission (2009). Annual Revenue Requirement filed by the Punjab State Electricity Board for financial year 2009-10, Chandigarh.

Punjab State Power Corporation Limited (2022) Communication received about proposals for reducing the burden of agriculture pumpsets Patiala.

Punjab Water Resources Department (2017), Groundwater Resources of Punjab, Punjab Government, Mohali.

Rasul, G. (2016). Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. Environmental Development, 18, 14-25.

Ray, I., & Gül, S. (1999). More from less: policy options and farmer choice under water scarcity. Irrigation and Drainage Systems, 13(4), 361-383.

Regy, P. V., Sarwal, R., Stranger, C., Fitzgerald, G., Ningthoujam, J., Gupta, A., & Singh, N. (2021). Turning Around the Power Distribution Sector: Learnings and Best Practices from Reforms, New Delhi: NITI Aayog and the Rocky Mountain Institute (RMI). Available at: https://rmi.org/insight/turning-around-the-power-distribution-sector

Ryan, M., Kolstad, J. R., Rockers, P. C., & Dolea, C. (2012), How to conduct a discrete choice experiment for health workforce recruitment and retention in remote and rural areas: a user guide with case studies' (No. 74489, pp. 1-94). The World Bank.

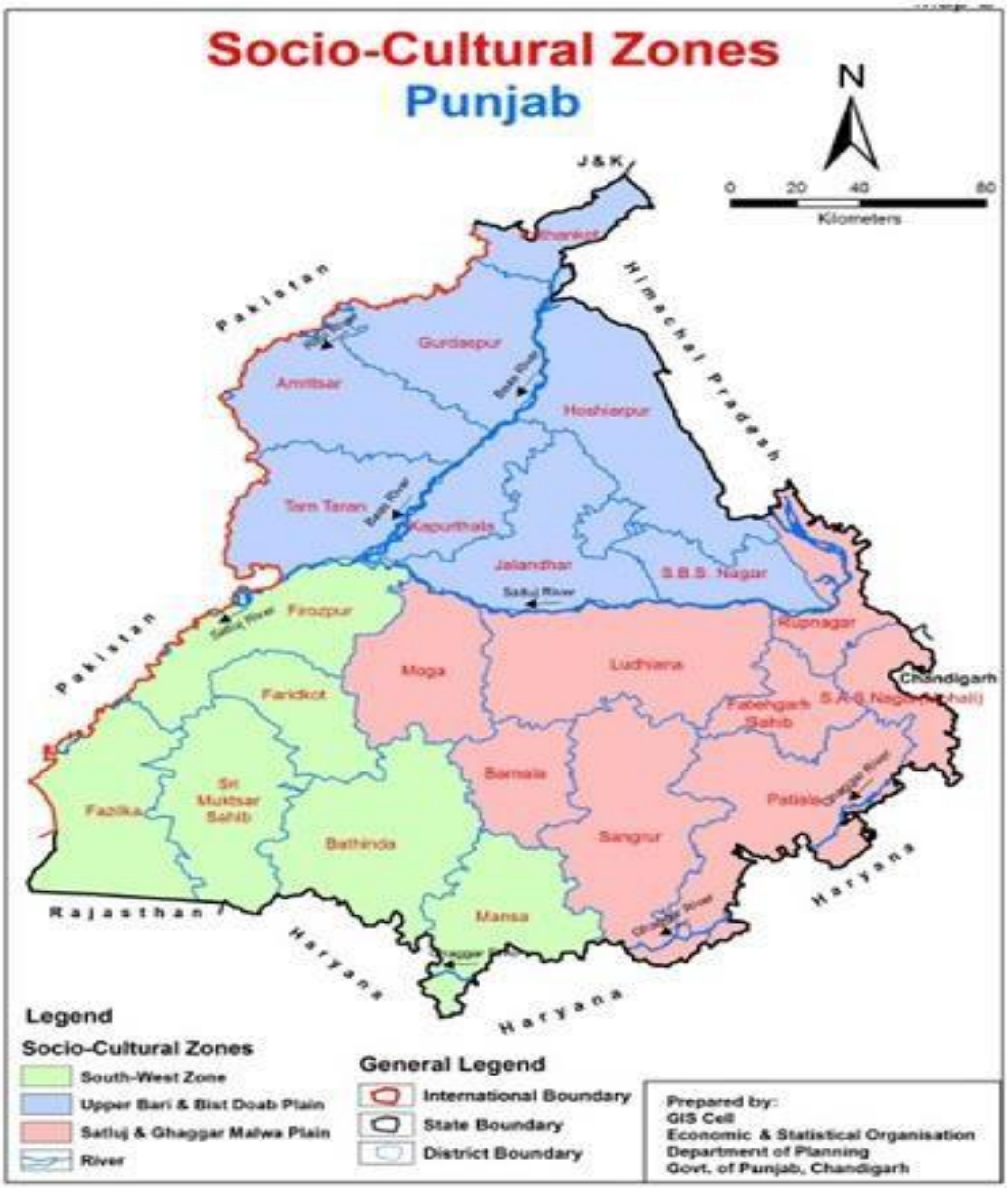
Sagebiel, J., & Rommel, K. (2014), Preferences for electricity supply attributes in emerging megacities—Policy implications from a discrete choice experiment of private households in Hyderabad, India. Energy for Sustainable Development, 21, 89-99.

Sarkar, A., & Das, A. (2014). Groundwater irrigation-electricity-crop diversification Nexus in Punjab: Trends, turning points, and Policy Initiatives. Economic and Political Weekly, 64-73.

Schaffitzel, F., Jakob, M., Soria, R., Vogt-Schilb, A., & Ward, H. (2020). Can government transfers make energy subsidy reform socially acceptable? A case study on Ecuador. Energy Policy, 137, 111120, 1-15.
Scott, C. A., & Shah, T. (2004). Groundwater overdraft reduction through agricultural energy policy: insights from India and Mexico. International Journal of Water Resources Development, 20(2), 149-164.
Sen, A., Nepal, R., & Jamasb, T. (2018). Have model, will reform? assessing the outcome of electricity reforms in Non-OECD Asia. The Energy Journal, 39(4), 181-209.
Shah, T. (2018). Kick-starting the Kisan Urja Suraksha Evam Utthaan Mahabhiyan. Economic and Political Weekly, 54, 13-16.
Sidhu, R. S., Vatta, K., & Dhaliwal, H. S. (2010). Conservation agriculture in Punjab-Economic implications of technologies and practices. Indian Journal of Agricultural Economics, 65(3), 413-427.
Singh, S., Kaur, M., & Kingra, H. S. (2008). Indebtedness among farmers in Punjab. Economic and Political Weekly, 130-136.
Singh, K. (2012). Electricity subsidy in Punjab agriculture: Extent and impact. Indian Journal of Agricultural Economics, 67(4), 617-632.
Smith, R. B., Nelson, H., & Roe, T. L. (2015). Groundwater and Economic Dynamics, Shadow Rents and Shadow Prices: The Punjab. Water Economics and Policy, 1(03), 1550014. 1-31.
Srivastava, S. K., Chand, R., Singh, J., Kaur, A. P., Jain, R., Kingsly, I., & Raju, S. S. (2017). Revisiting groundwater depletion and its implications on farm economics in Punjab, India. Current Science, 113(3), 422-429.
Statistical Abstract (2020), Economic and Statistical Organization, Department of Planning, Government of Punjab.
Statistics of Punjab Agriculture (2020), Punjab Agriculture University, Ludhiana.
Swain, A., & Charnoz, O. (2012). In Pursuit of Energy Efficiency in India's Agriculture: Fighting 'Free Power' or Working with it?. Agence Française de Développement. Working Paper, 126, 1-80.
Swain A. K., & Mehta, U. S. (2014). Balancing State, utility and social needs in agricultural electricity supply. International Institute of Sustainable Development, 1 -15.
Tesfaye, A., Hansen, J., Kassie, G. T., Radeny, M., & Solomon, D. (2019). Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach. Ecological Economics, 162, 157-168.
Wang, T., Park, S. C., & Jin, H. (2015). Will farmers save water? A theoretical analysis of groundwater conservation policies. Water Resources and Economics, 12, 27-39.
Wang, X., & Lin, B. (2017). Electricity subsidy reform in China. Energy & Environment, 28(3), 245-262.
Winett, R. A., Kagel, J. H., Battalio, R. C., & Winkler, R. C. (1978). Effects of monetary rebates,

feedback, and information on residential electricity conservation. Journal of Applied Psychology, 63(1), 73-80.
Wong, J. C. Y., Blankenship, B., Urpelainen, J., Balani, K., Ganesan, K., & Bharadwaj, K. (2022). Understanding electricity billing preferences in rural and urban India: Evidence from a conjoint experiment. Energy Economics, 106, 105735., 1-12.
Worley, H., Pasquier, S. B., & Canpolat, E. (2018). Energy Subsidy Reform Assessment Framework: Designing Communication Campaigns for Energy Subsidy Reform; World Bank: Washington, DC, USA, 2018.
Vagliasindi, M. (2012). Implementing energy subsidy reforms: an overview of the key issues. World Bank Policy Research Working Paper, (6122), 1-34.
Verme, P. (2016). Subsidy reforms in the Middle East and North Africa region: a review. World Bank Policy Research Working Paper, (7754), 1-34.
Vidican Auktor, G., & Loewe, M. (2022). Subsidy Reform and the Transformation of Social Contracts: The Cases of Egypt, Iran and Morocco. Social Sciences, 11(2) (85), 1-22.
Viswamohanan, A., Sharma, S., Aklin, M., & Moerenhout, T. (2022). Targeting Agricultural Electricity Subsidies in Haryana. International Institute for Sustainable Development, 1-39.
Von Moltke, A., McKee, C., & Morgan, T. (2004). Energy subsidies: Lessons learned in assessing their impact and designing policy reforms. Management of Environmental Quality: An International Journal, Vol. 15 No. 4, pp. 459-460.
Zhu, T., Ringler, C., & Cai, X. (2007, January). Energy price and groundwater extraction for agriculture: exploring the energy-water-food nexus at the global and basin levels. In International Conference of Linkages Between Energy and Water Management for Agriculture in Developing Countries, Hyderabad, India.
Zilberman, D., Sproul, T., Rajagopal, D., Sexton, S., & Hellegers, P. (2008). Rising energy prices and the economics of water in agriculture. Water policy, 10(S1), 11-21.

Figure 2:20 Socio-Cultural divisions of Punjab



Source: Department of Planning, Punjab

3. Chapter: A discrete choice experiment to estimate farmers' preferences for low-water rice variety in Punjab

3.1: Introduction

The Green Revolution was a turning point in achieving food self-sufficiency for India with Punjab State at the forefront of the nation's efforts in the 1960s. It was seen as a cornucopia for a newly independent country struggling with issues of hunger and malnutrition. The introduction of the new seed-fertilizer-technology produced impressive results in reversing the food crisis and stimulating agricultural growth, particularly record increases in wheat and rice productivity. As far as the issue of electricity subsidy to agriculture is concerned, it got compounded with the government's decision to give free electricity to agriculture in 1997, which was mainly done for reasons of political expediency. However, the long-term implications of these policies were not envisaged at the appropriate level and time. Questions are now being raised about the sustainability of this intensive agriculture strategy. 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 crucial for the major rice-wheat belt in Punjab, the breadbasket of India. The state with only 0.03 percent of the world's geographical land 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 has increased irrigation water requirements tremendously. The number of pumps has increased from 0.192 to 1.476 million in the last 50 years. The excessive pumping of groundwater for irrigation has created a declining water table situation. The average rate of decline in the last few years has been 55 cm per year. The cultivation of the preferred long-duration rice variety Pusa 44 in Punjab is associated with increased crop water requirement. Experts recommend switching to short-duration and superior quality basmati rice, which has lesser water requirements (Aggarwal et al., 2009).

However, under the prevailing conditions of minimum support price and free electricity, the long- duration rice variety remains the most remunerative choice. The switch to low-water rice varieties is slow, aggravating both the groundwater crisis and increasing financial burden of electricity subsidies. The preference for Pusa 44 is explained by the lack of economic incentives to grow newer and more sustainable varieties (Joshi et al., 2018). However, there is little empirical evidence about the economic incentives and electricity tariffs acceptable to farmers, if they were offered a menu of choices bundling different economic incentives such as area- based payments and minimum assured prices and electricity rates such as fixed monthly charges and load-based tariffs. Farmers' preferences for these trade-offs are likely to be heterogeneous, while some farmers might value area-based payments, others might accept assured prices. And others might be willing to give up part of the free electricity for economic incentives to augment their income levels. A thorough analysis of such preference heterogeneity can help in designing targeted and differentiated incentive schemes. Consideration of heterogeneity in preferences and associated willingness to pay is important for achieving environmental objectives (Jaeck and Lifran, 2014, Jin et al., 2020).

The discrete choice method is an efficient tool to understand farmers' choices for alternative varieties and willingness to trade off free electricity for better returns of more environmentally sustainable alternative crops. The potential adoption of resource-efficient rice varieties requiring comparatively less water and willingness to pay for electricity was estimated based on two stated preference experiments conducted with 859 farmers in Punjab in 2021-22. The chapter sheds light on the key attributes that can drive adoption decisions and payment behavior and allows estimation of willingness to pay/willingness to accept the different incentive and electricity price attributes.

This paper is organized in six sections: Section 3.2 presents a description of the problem. Section 3.3 reviews the relevant literature. Section 3.4 discusses the discrete choice methodology applied in this chapter. Section 3.5 presents the results of the conditional logit and random effects probit models. Section 3.6 reviews the results and policy implications, and Section 3.7 offers conclusions.

3.2: Description of Problem

Punjab farmers prefer water-intensive and long-duration Pusa 44 paddy varieties, despite the availability of shorter-duration rice varieties such as PR 121, PR 126, and Basmati rice varieties (Joshi et al., 2018). There is a clear economic advantage in growing Pusa 44 rice due to higher yield and consequently better economic returns. Comparatively, the early maturing rice varieties, which can reduce water and energy demand for rice production, lag in terms of profitability. Pusa 44 gives better comparative returns due to low production and marketing risk. Policies suggested to address groundwater over-extraction include encouraging farmers to adopt low-water crops in Punjab. 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 could substantially reduce the common pool losses if coupled with marginal cost pricing (Sayre and Taraz, 2019). Punjab Agriculture University has advised farmers to avoid the cultivation of Pusa 44 and adopt short-duration and Basmati rice varieties to save water and manage paddy straw (PAU 2022).

Pusa 44 rice consumes 30 percent additional energy in pumping 16 percent additional volume of water as compared to the short-duration varieties (Joshi et al., 2018). It is estimated that the short-duration rice variety saves 35 cm per hectare of groundwater and takes 35 days less than Pusa 44 rice (Brar 2021). The expenses on fertilizers, plant protection measures, human labor use, and diesel for irrigation were found to be considerably higher in Pusa 44 variety vis-à-vis short-duration varieties (Singh et al., 2022). It has been projected that the state could save 7 billion cubic meters of groundwater and $92.14 million worth of electricity subsidy by shifting to short-duration varieties in 2022 (Hindustan Times, 2022). Farmers select long-duration rice varieties keeping in view the highest gross returns obtained for Pusa 44 rice. The difference in grain yield between Pusa 44 and PR 126 has been estimated to be at least 5.5 q/ha (Manan et al., 2018).

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 (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). Price variability was an important marketing problem faced by basmati growing farmers (Grover 2012). The major problem during the marketing of basmati was the exploitative practices by intermediaries and the lack of public procurement (Gohain and Singh, 2018). The absence of assured procurement and high price volatility in the open market discourages the cultivation of the basmati crop in Punjab.

A related problem is the role of free electricity in boosting the cultivation of the long-duration water-intensive rice variety. The marginal cost of pumping groundwater is zero and farmers do not face the economic cost of cultivating high-water crops. Free power results in over-exploitation of groundwater, lowering groundwater levels, rising cost of drilling, piling up of power subsidies, expanding water-guzzling crops even in water-scarce areas, and failure of borewells leading to farmer's distress (Fosli et al., 2021). It is argued that eliminating energy subsidies for groundwater pumping may not encourage farmers to switch to less water-intensive crops (Bhattarai et al., 2021). Offering financial incentives is expected to encourage a shift to less water-intensive crops in groundwater-scarce regions (Sidhu 2020 et al.,).

Substitution by short-duration variety and basmati variety by farmers in Punjab will depend on reducing the variation in net returns from these varieties. Farmers are likely to voluntarily adopt low-water crops if they are adequately compensated. Some Indian states offer incentives for shifting to non-paddy crops. There is evidence that strategies involving economic incentives and long-term technological packages can foster the adoption of sustainable agriculture practices by farmers (Bopp et al., 2019). In this context, Punjab farmers' preferences has been examined for the potential introduction of economic incentives to adopt low-water crops and willingness to trade off free electricity for these incentives, a subject that has huge policy interest, because of its environmental impact.

3.3: Review of Literature

3.3.1: Role of Subsidies

Welfare economists often justify the use of input subsidies for reasons of market failure and externalities. Input subsidies, whether direct or indirect are widely used, particularly in agriculture. The input subsidy program in India in the 1960s helped farmers during the Green Revolution and had a positive effect on food security (Kannan 2014). The impact of subsidies on increasing agricultural productivity in the European Union has been extensively studied (Rizov et al., 2013). In China, Liancui and Honghui (2010) found that subsidies had the effect of encouraging farmers to increase crop output.

However, there is rich evidence of significant problems with the design and implementation of input subsidies. Gautam (2015) lists out serious drawbacks of input subsidies, from the enormous hidden and unintended long-term costs to how they appear to compromise the very objectives they were originally intended to achieve. In making a case against input subsidies, the paper cites the example of public procurement of rice correlated with excessive groundwater use powered by subsidized electricity in water-scarce Indian states, which is compromising long-term food security by contributing to a rapid decline in groundwater levels in the traditional breadbaskets of the world. This was corroborated by the finding of a significant negative impact of electricity subsidies on groundwater, with the elasticity of groundwater level to electricity subsidies estimated at a substantial -0.67. There is empirical evidence that electricity subsidies drive the expansion of water-intensive crops, primarily rice (Badiani and Jessoe, 2012). A negative relationship of diversification with irrigation intensity observed by Jha et al., (2009) indicates that an increase in irrigation is leading to specialization in paddy and wheat crops and discouraging diversification.

Secondly, the basis of economists' criticism of input subsidies is the opportunity cost of tying down scarce fiscal resources to unproductive uses and the political economy of scaling back subsidies which have limited effectiveness. Another significant implicit cost of input subsidies is that they may be diverting funds that could have been used for building the necessary infrastructure for the farm sector (Gulati and Sharma, 1995). A study found that input subsidies had negatively and significantly affected public investment in Indian agriculture in both the long-run and short-run at the national as well as at the state level (Akber 2020). Thirdly, a major concern is that input subsidies encourage over-use and ineffective use of the subsidized input. A study of paddy cultivators in Sri Lanka found the induced overuse of fertilizers due to fertilizer subsidy (Gautam 2015). Another form of economic waste arises from poor targeting of the input subsidies as universal subsidies tend to be regressive. The major beneficiaries are the relatively larger farmers instead of the small and medium farmers. It is also observed that prolonged use of input subsidies may jeopardize long-term sustainability. Subsidized electricity and the relative price-driven nutrient imbalance in fertilizer use were statistically linked to negative impacts on total factor productivity. The partial productivity of fertilizer has declined consistently since the 1970s (Gautam 2015). Therefore, significant problems associated with input subsidies put a question mark on their continued expenditure.

On the other hand, economists argue that an output subsidy is more efficient than an input subsidy as a means to encourage more production of a good. The argument runs that, irrespective of whether the effect on the output of either subsidy is corrective or distorting, the input subsidy does, and the output subsidy does not, distort the choice of inputs away from the least-cost combination (Parish and McLaren, 1982). Secondly, input subsidies may be used to encourage the expansion of activities or whole sectors using some specific input, rather than the output of particular products. 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). There are instances of preference for a combination of price support and input subsidies over a price support or input subsidy 'monopolicy' (Bayes et al., 1985). Another study on Bangladesh found that changes in the procurement prices for food grains have a relatively greater impact on output supply and input demand than do changes in the level of fertilizer subsidies and given the current levels of output prices and input subsidies, output price support may involve somewhat higher foreign exchange savings and slightly less government spending than fertilizer subsidies to induce the same percentage impact on output (Nehring 1991).

Studies have established 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) reported 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. Hence, governments have been implementing agricultural support policies for farmers. For instance, in Turkey, the primary means of intervention are deficiency payments for cotton and floor prices for grains and oilseeds (Demirdogen et al., 2021). The difference between the target price and the market price is determined as the deficiency payment to be paid to the grower in Turkey.

A historical review of cross-country experience shows that Governments in Asia have used grain price stabilization as a major policy instrument for promoting the Green Revolution, beginning in the 1960s. The Green Revolution launched to boost food grain production and ensure food security required stable prices for sustained success. Many Asian countries stabilized grain prices at or above world price levels: India stabilized domestic prices well above world prices except for a few years (Cummings et al., 2006). China too maintains price stabilization, including minimum procurement prices for rice and wheat. The grain floor price program in China helped to significantly increase the strategic grain reserve (Fang, 2010). Developed countries have also used government measures to ensure remunerative prices and incomes for farmers and boost agricultural production after the Second World War, though at the high cost of support and excess production.

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 assured high returns 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). The most important influencing factor for farmers to change crops was found to be the 'economic return' of the crop and 'market factors' (Mehdi 2018).

Ostwald et al., (2013) found that economic motivations were strong, but values, knowledge, and legal conditions were also crucial for a change to energy crops. Sattler and Nagel (2010) observed that despite the general assumption that farmers' decisions were mostly driven by economic rationality, associated risks, effectiveness, or time and effort necessary to implement a certain measure were equally important depending on the specific situation. Farmers' perception significantly affects their adoption decisions (Adesina and Baidu-Forson, 1995, Silvano et al., 2005). Perception may be influenced by various factors (Wei et al., 2007) and may differ according to the characteristics of farm households (Deressa et al., 2009, Gbetibouo, 2009).

At the same time, there is growing evidence of the use of incentives to promote sustainable resource use (Repetto 1987, Bopp et al., 2019). Policymakers have attempted to decrease rates of water extraction through incentive-based measures in many countries. The United

States offers farmers cash payments as incentives to adopt conservation practices through initiatives such as the Conservation Reserve Program (Cox 2006). Countries have implemented administrative, legislative, or management controls, including economic incentives to reduce the demand for water (Molle 2003).

While there may be several promising technological and policy solutions to promote ecologically sound crop production. However, several win-win conservation strategies and measures which could be beneficial both to farmers and the environment may not be successfully implemented due to little consideration given to farmers' point of view. The participation of farmers is central to reversing the decline of environmental quality on agricultural land. Farmers' preferences for elements of scheme design influence the likelihood of their participation. Modeling farmers' choices can help in estimating the trade-offs for different design elements and the knowledge of these tradeoffs can inform the design of incentive schemes to be offered to potential participants (Ruto and Garrod, 2009).

3.3.2: Discrete choice experiments

The stated choice method has emerged as an important tool to understand farmers' preferences for the adoption of sustainable practices. Asrat et al., (2010) investigated Ethiopian farmers' crop variety preferences, their mean willingness to pay for each crop variety attribute, and the influence of household-specific and institutional factors on these preferences. Environmental adaptability and yield stability were found to be important attributes for farmers' choices of crop varieties. Farmers were willing to forgo some extra income or yield to obtain a more stable and environmentally adaptable crop variety.

A discrete choice experiment was employed to examine farmers' preferences for drought tolerance (DT) traits and heterogeneity in these preferences in rural Bihar (Ward et al., 2013). The results showed that farmers valued the reduction in yield variability offered by DT cultivars 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 behavioral parameters not only significantly influenced choice probabilities but also affected the way farmers valued different seed attributes.

Applications of choice experiments have also focused on the adoption of emerging technologies in agriculture. Hubbell et al., (2000) combined revealed preference data with stated preference data to estimate willingness to adopt Bt cotton varieties (genetically modified pest-resistant plant variety) in the United States. The estimated mean willingness to pay for Bt cotton ranged from $14 per acre for upper south growers with no education and no experience with resistant insect populations to $40 per acre for lower south college educated and experienced farmers. Qaim and De Janvry (2003) analyzed the adoption and impact of Bt cotton in Argentina based on revealed and stated preferences. The new technology was found to reduce insecticide applications and increase yield, but the high price charged for genetically modified seeds reduced its profitability. Farmers' willingness to pay was less than half the actual technology price.

Breustedt et al (2008) explored farmers' willingness to adopt genetically modified oilseed rape before its commercial release and estimated the demand for the new technology. A choice experiment with 202 German farmers 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. Neighboring farmers' attitudes towards genetically modified cropping and several farmer and farm characteristics were significant determinants of prospective adoption. Demand simulations suggested that adoption rates were very sensitive to the profit differences between genetically modified and non-genetically modified rapeseed varieties. This study draws useful information about the selection of attributes and conduct of discrete choice experiments with farmers from the above studies.

Krishna and Qaim (2007) analyzed the ex-ante adoption of insect-resistant Bt eggplant technology in India and estimated farmers' willingness to pay using the contingent valuation method. The mean willingness to pay for Bt hybrid seeds was Rs. 4642/acre ($106), which was more than four times the price of conventional hybrids and more than ten times the current average seed cost of Rs. 440/acre from overall seed sources. Kolady and Lesser (2006) estimated farmers' willingness to pay for Bt and non-Bt eggplant varieties in two different ways, depending on the variety's breeding method (hybrid or non-hybrid).

A choice experiment conducted to examine farmers' preferences for incentives to shift from the current farming system to context/crop-specific climate-smart agriculture found strong linkages between the payment vehicle, land tenure, property rights, and farmers' preferences for climate-smart agriculture. (Shittu et al., 2018). All other things being equal, the marginal willingness to adopt for an average farmer in Nigeria was $122.62 per hectare for good agricultural practices with manure, $22.21 for good agriculture practices without manure, and willingness to pay was $5.15 per hectare to avoid a shift to agroforestry.

A stated preference experiment explored farmers' prospective responses to the "greening" of the Common Agricultural Policy in Germany (Schulz et al., 2014). Participants were asked to choose between a greening option with a given set of management prescriptions and an opt-out alternative with a stipulated cut of the single direct payment. Greening was perceived as a costly constraint to farming by farmers. A discrete choice experiment found the attributes of crop yield, labor requirement, and cost of production to be significant in influencing small-scale farmers' attitudes towards conservation agriculture (Barrowclough and Alwang, 2018).

To develop strategies for inducing farmers to grow energy crops, studies have applied choice modeling framework. A choice experiment assessed the relative value of characteristics associated with growing energy crops and identified the willingness of farmers to grow energy crops relative to different levels of income and subsidies based on predictions of acreage of energy crop cultivation (Paulrud and Laitila, 2010). A choice experiment was conducted to assess farmers' preferences for adopting several good agricultural practices, such as precision fertilization, crop diversification, catch crops, peatland protection, extensive use of meadows, and the reduction of livestock stocking density based on trade-offs made between payments and varied requirements of agri-environmental scheme contracts, and preferences disclosed for contractual attributes (Czajkowski et al., 2021).

Previous research has examined farmers' attitudes and preferences for adopting certain crops. Information on the relative valuation of economic incentives to motivate farmers to adopt sustainable varieties of the same crop is lacking. Understanding farmers' preferences for substituting short-duration and basmati varieties in Punjab is crucial for the economic and environmental sustainability of cropping systems. Policies made without the study of farmers' preferences may render crop diversification efforts ineffective. Because the farmer invests time, money, and inputs, understanding the ways in which farmers decide upon alternative varieties and the drivers of these decisions is crucial for developing appropriate and sustainable policies. To address this research gap, a choice experiment has been conducted in Punjab to explore farmers' preferences for adopting low-water shorter duration, and basmati rice varieties.

While discrete choice experiment methodology is considered as one of the best quantitative techniques for eliciting preferences, the credibility of stated preference surveys has been questioned substantively in the literature for many years. One central criticism concerns the hypothetical nature of the method which has been claimed to instigate respondents to overstate their 'true' willingness to pay. This is because the assessment exercise is based on a simulated scenario, hence a "hypothetical bias" may occur *i.e.* the preferences expressed by the survey respondents may differ when facing real economic circumstances. Hence, respondents may exert free-riding or strategic behavior in their responses, or they may be susceptible to yea-saying or warm glow effects (Merkbak et al., 2014). Few studies have made systematic connections between the stated choice settings and the real world. Johansson-Stenman and Svedsäter (2012) found that the hypothetical marginal willingness to pay *(*MWTP*)* for a moral good (contributions to a WWF project) was significantly higher than the corresponding real-money MWTP*,* whereas no hypothetical bias was seen for an amoral good (a restaurant voucher). Chang et al., (2009) found that the non-hypothetical choices were better approximation of "true" preferences than are hypothetical choices in predicting actual grocery store sales for three different product categories (dishwashing liquid, ground beef, and whole wheat flour). In a study of a choice between beef ribeye steaks with varying qualities in both hypothetical and non-hypothetical contexts, Lusk and Schroeder (2004) inferred that hypothetical choices overestimate total willingness-to-pay for beef steaks while observing insignificant differences in marginal willingness-to-pay for a change in steak quality across the hypothetical and actual payment contexts. In a unique stated choice-revealed choice study in the transport domain, Brownstone and Small (2005) showed that the value of times inferred from the stated choice experiments considerably underestimated the corresponding value derived from the revealed choice setting. People's actual route choices indicated that they are willing to pay much more to save time (or more precisely, to avoid delay) than what they state.

The issue of hypothetical bias has been investigated and treated in a number of ways in the literature, for instance by introducing budget reminders and cheap talk scripts or by seeking to decrease interviewer effects or by increasing scenario realism (Haghani et al., 2021*).* For this analysis based on hypothetical and stated choices of compensation schemes, some randomness of choice on the farmer's side is expected. The randomness of choice is expected to be heterogeneous across respondents. Segmented estimation is applied by the author in this study to understand the heterogeneity of choice behavior. This helps to relate variations in individual's preferences to their socio-economic and demographic characteristics.

3.4: Discrete choice experiment approach

3.4.1: Context of valuation of the proposed objectives and attributes

The focus of this choice experiment is on examining the effect of economic incentives on influencing the adoption of low-water rice varieties. The empirical analysis relies upon two discrete choice experiments conducted on paddy-growing farmers in the Indian state of Punjab. Using stated preference data from twenty districts of Punjab, this study aims to (1) understand farmers' preferences for shifting from the high-water paddy variety to the newly developed short-duration and basmati (superior) rice varieties, which require comparatively less water for cultivation, (2) analyze whether farmers' preferences are conditioned by the level of the economic incentive and expected net returns, (3) understand how the preferences are affected by demographic, socio-economic and regional factors, and (4) determine whether farmers are willing to trade off free electricity for incentives to invest in alternative rice varieties. In economics literature, the choice experiment is the established method for conducting such valuation studies. Experiment A examines farmers' preferences for the adoption of short-duration rice variety with the offer of area-based payment per acre. Experiment B studies farmers' preferences to adopt basmati on the offer of a minimum assured price per quintal.

It has been empirically established that farmers are more influenced by economic incentives than any other factor. Incentives have encouraged the adoption of best agriculture practices (Wade et al., 2015, Purola and Lehtonen, 2022). 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 European Union's Common Agricultural Policy uses area payments and minimum guaranteed prices to support arable crops (Sckokai and Moro, 2006).

Drawing upon these international experiences, the two choice experiments aim to determine the likelihood of adoption of resource-efficient rice varieties with the offer of economic incentives in the form of area-based payments and minimum guaranteed prices to farmers in Punjab. Since the scope of the experiment was to examine farmers' preferences for planting more short-duration and basmati varieties by offering area-based payments and minimum guaranteed prices, the number of attributes was restricted to those most likely to influence the substitution pattern between the two varieties and willingness to pay electricity charge on monthly basis or connected load basis. The two attributes chosen based on interviews with farmers and the pilot study were: (1) Economic incentive for adopting low-water rice variety, and (2) Price of electricity.

Both the stated preference experiments have two attributes with three levels each. 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. Attributes and levels are presented in Figure 3.1 and an example of a choice set for each of the two experiments is shown in Figure 3.2 and Figure 3.3.

3.4.2: Description of Attributes and levels

3.4.2.a: Economic incentive for adoption

The stated preference experiment includes an attribute of area-based payment for adopting short-duration rice and a minimum assured price for basmati rice. The farmer is likely to lose money by substituting short-duration variety and basmati variety as the long-duration rice variety has the highest yield and is purchased at the minimum support price. The income loss suffered by farmers shifting to short-duration rice variety due to lower yield per hectare (acre) is proposed to be compensated by awarding lump sum payments on a per acre basis. Similarly, in the case of basmati, a minimum assured price, similar to the minimum support price is expected to reduce the uncertainty associated with the increased price volatility in the market. This attribute has three levels in both the choice experiments. As yield potential is comparatively lower for short-duration rice vis-a-vis long-duration variety, area-based payment on a per acre basis was selected. On the other hand, a minimum assured price per quintal was presented to encourage the adoption of basmati which has a larger yield difference. Such economic incentives can compensate farmers and encourage them to replace long-duration paddy with short-duration rice and basmati variety.

The attribute of incentive-linked diversification 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). Drawing on these experiences, the attribute of incentive-linked adoption of resource-efficient varieties was included in the study.

In the choice experiment on determining farmers' preferences for adopting short-duration variety PR 121 and PR 126, the three levels of the area-based payment were – Rs. 4000 per acre, Rs. 4200 per acre, and Rs. 4500 per acre. The choice experiment investigating farmers' preferences for adopting basmati had three levels of minimum assured price of Rs. 3000 per quintal, Rs. 3200 per quintal, and Rs. 3500 per quintal. To ensure that farmers were presented with credible estimates of the yields and consequent cash payments to compensate for the lower returns, this study relied on the estimated yields of the different varieties collated by the Punjab Agriculture University and the actual average yield data obtained by farmers in the last three years as available on the government of Punjab website. These estimates were cross-checked with participants during interviews.

On average, the minimum difference of two quintals per acre is reported between the long-duration and short-duration rice varieties. Given the minimum support price of Rs. 1960 per quintal for paddy, the monetary loss to a farmer would be at least Rs. 3920 per acre, rounded off to Rs. 4000 ($50.22) per acre. By applying higher doses of inputs, including fertilizers and pesticides, many farmers can obtain higher yields, and hence the monetary loss may be bigger. Based on pilot studies, the area-based payment was increased by five percent and twelve percent to offset income losses by farmers likely to choose the resource-efficient short- duration rice variety. As a result, the second level of the area-based incentive payment of Rs. 4200 ($52.73) per acre and the third level of Rs. 4500 ($56.50) per acre were presented to the farmers in the first stated preference experiment on substitution of long duration rice variety with short-duration variety.

There are significant yield differences in the range of 10-12 quintals per acre between the water-intensive long-duration rice variety and superior quality basmati variety. A mismatch between demand and supply has caused a crash in basmati prices in the past (Sidhu 2014). The risk of facing monetary loss forces basmati growing farmers to sell at the minimum support price notified for ordinary rice. The lack of interest in the adoption of basmati due to price variability in the open market can be addressed by offering minimum assured price. Therefore, the first level of minimum assured price of Rs. 3000 ($37.66) per quintal was presented to ensure an almost similar income to the farmer substituting long-duration Pusa 44 variety with basmati rice. Based on the views expressed by farmers during the pilot study, the assured minimum price was increased by six percent and sixteen percent to arrive at the figure of Rs. 3200 ($40.18) per quintal and Rs. 3500 ($43.94) per quintal for the second and third level of the attribute for the second stated preference experiment on basmati variety adoption.

The status quo alternative presented to the farmer was to continue with the conventional long-duration rice variety Pusa 44, and not earn any incentive. The existing cropping choice option was introduced because this is the variety with which farmers are most familiar and is most widely used. Some farmers are expected to select the existing crop option because of subjective concerns about perceived yield differences and risks associated with cultivating environmentally sustainable varieties.

3.4.2.b: Price of electricity

The second attribute is electricity tariff either at a fixed monthly rate or on a load basis (per horsepower per month). Two types of flat-rated tariffs based on fixed monthly rate and on the basis of load have been applied in the choice sets to evaluate the willingness to pay. The study aims to identify willingness to pay without enforcing meter installation.

Power utilities across different states in India use two common tariff modes to charge groundwater consumers: flat tariffs, where payments are fixed according to a pump's power rating, and metered tariffs based on units of power actually consumed. Flat tariffs are recognized for imposing lower administrative costs and more equitable distributional outcomes but provide no incentive to farmers 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). De Fraiture and Perry (2002) argue that the energy costs at which demand becomes elastic to pricing are too high to be socioeconomically and politically feasible. The price has to be set at such a level that the marginal cost becomes higher than the marginal return to control groundwater draft. This is the reason for disenchantment with metered tariffs (Kishore and Verma 2004, Sidhu et al., 2020). Further, withdrawal of subsidies would need to occur as metered rate at the currently subsidized levels is not likely to encourage groundwater conservation, a move which would meet stiff opposition in the prevailing subsidy regime. It has been observed that one of the main causes of opposition to electricity payment is metering (Mukherji and Das, 2014). Therefore, this chapter did not apply metered tariff in the discrete choice analysis.

The three levels of flat-rated electricity price presented to the farmers include, (1) Zero electricity charge with a nominal enrolment fee of Rs. 100 ($1.25) per year, (2) Fixed monthly flat rate electricity charge of Rs. 100 ($1.25) per month and (3) Load-based tariff of Rs. 10($0.12)/HP/month based on the sanctioned load of the farmer.

The first level of the price attribute was a nil payment charge except for a nominal annual enrollment fee of Rs. 100 per pump. As the imposition of electric charge is expected to encounter opposition from farmers, a nominal charge along the lines of a lifeline tariff was included in the experiment. Very high electricity charges would not be affordable for marginal and small farmers. A fixed monthly charge is being paid for electricity by agriculture consumers in some Indian States. Drawing upon these experiences, a monthly charge of Rs. 100 per month per pump was selected as the second level to estimate willingness to pay.

Low fixed charges based on horsepower have been paid by farmers for electricity in the past. Before the policy of free electricity was introduced in 1997, a flat rate was levied on agriculture consumers. A look at the previous tariff orders shows that farmers paid a flat rate of 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 for the price of electricity attribute as this would be similar to what farmers would have been paying before the policy of free supply. A very high flat rate was not included in the experiment to elicit genuine willingness to pay and not discourage payment behavior. Further, a metered rate was avoided as there is strong opposition to metering among Punjab farmers.

In terms of cost recovery, the nominal fixed tariffs are not profitable for the distribution utility, but they would meet less resistance. For instance, the rate of power supply applicable to agriculture consumers as per Tariff Order 2022-23 is 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 in our analysis is that we would be able to evaluate the 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 tariff would impose higher burden on consumers with higher capacity motors and discourage farmers from using higher capacity motors in the long run.

Figure 3:1 Attributes and Levels for Experiments A and B

	Experiment A	Experiment B
Incentive for alternative paddy variety	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 3:2 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 3:3 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 FLAT RATE! 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. Nine choice cards were presented to each farmer with a binary choice – willing to change rice variety and pay for electricity or not willing to accept the policy alternative. The choice data was used to examine the preferences of farmers in Punjab to accept incentives, either area-based payment per acre or minimum assured price for adopting low-water rice varieties and willingness to move away from free electricity and pay for electricity. To my knowledge, no previous study has explicitly examined this issue. Most farmers were well conversant with the cost and revenue streams associated with the three rice varieties. Their understanding was enhanced by providing a summary of the pros and cons of adopting the different varieties before the choice experiment.

For each choice scenario, respondents were asked to indicate whether they were likely to prefer the hypothetical offer of economic incentive to adopt the resource-efficient rice variety and pay an electric charge or not. 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 economic incentive or not?") was adopted as it better reflects the nature of the problem faced in agricultural consumption of electricity in Punjab. The purpose of the study was explained to the farmers selected randomly. A description of each of the attributes and levels was provided at the beginning of the questionnaire. The respondent's identity was kept confidential. It was checked whether the respondent always chose the alternative with the highest level of an attribute or in other words, are there dominant preferences. In general, there were extremely few dominant preferences.

The analysis used 859 questionnaires completed by farmers, yielding 7731 observations for each experiment, as each respondent was shown nine choice cards within a binary choice framework. The main socio-economic variables of interest were age, education, land acres owned, sanctioned load, and the number of tube wells owned. The dummy variables of interest include incentive levels and levels of electricity rate. The usual method to account for non-linearities is to add dummy variables in the analysis. Each level is assigned a separate variable, that is one if the level is present and zero otherwise. By doing so, the effect of each level is estimated separately. If the estimated parameters of the dummy variables differ, non-linearity can be assumed. Regarding the structure of the utility function, linear effects of the attributes on utility are assumed i.e., a change from level 1 to level 2 has the same effect as from level 2 to level 3.

3.4.3: 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

$$U_{in} = V_{in} + \varepsilon_i \tag{3.1}$$

$$i = 1, \dots. I \; and \; n = 1, \dots \dots N,$$

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

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

$$= P_r[V_{in} + \varepsilon_{in} \geq V_{jn} + \epsilon_{jn}] \tag{3.2}$$

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

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 (3.1) 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 (3.2) is logistically distributed, the probability of farmer *n* choosing alternative *i* is given by

$$Pni = \frac{exp\mu(Vin)}{\sum_{j=1}^{n}(exp(Vjn)} \quad (3.3)$$

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

$$P(yes|yes, no) = exp(V_{yes})/[exp(V_{yes}) + exp(V_{no})] \quad (3.4)$$

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 (3.4) can be rewritten as

$$P(yes|yes, no) = exp(V_{yes})/[exp(V_{yes}) + 1] \quad (3.5)$$

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

$$\frac{P(yes|yes,no)}{P(no|yes,no)} = \frac{exp(Vyes)/exp(Vyes)+1}{exp(Vno)/exp(Vyes)+1} = \frac{exp(Vyes)}{exp(Vno)} \quad (3.6)$$

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,

$$log\ e\frac{P(yes|yes,no)}{P(no|yes,no)} = Vyes \quad (3.7)$$

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

$$Vyes = \sum_{K} \beta_k X_k + \sum_{m} \alpha_m Z_m \quad (3.8)$$

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

$$Adoption_{in} = \beta_0 + \beta_1 \mathrm{x}\ Incentive1_{\mathrm{in}} + \beta_2 \mathrm{x}\ Incentive2_{\mathrm{in}} + \beta_3 \mathrm{x}\ Incentive3_{\mathrm{in}} + \beta_4\ \mathrm{x}\ Electriccharge1_{in} + \beta_5 x\ Electriccharge2_{in} + \varepsilon_{in} \quad (3.9)$$

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 incentive 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:

$$Willingness\ to\ pay = \frac{\beta_{Inc}}{\beta_p} \tag{3.10}$$

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

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

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

$$= \frac{1}{1+e^{(-V_{int})}} \tag{3.11}$$

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., 2007). 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.

3.4.4: Estimation strategy

A conditional logit model and random effects probit model was applied to estimate respondent preferences for economic incentive and electricity price attributes. 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 behavioral 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., 2007).

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 across observations. Assuming a linear utility function V(.), the utility to be estimated for moving from long-duration rice variety to short-duration resource efficient rice variety can be given as

$$\Delta V = \alpha_{1SD} xPayment + \alpha_{2SD} xPrice + \theta \quad (3.12)$$

where ΔV is the change in utility in moving from long-duration rice variety to short-duration rice variety, 'Payment' is the difference in the level of area-based 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 adoption of low-water rice variety; it is observed for each discrete choice whether the individual chooses long-duration or short-duration rice variety. ΔV is a binary variable, taking the value of 0 if the individual chooses long-duration rice variety and 1 if the individual chooses short-duration variety. Random effects probit 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.

3.5: Empirical Results

i) Results of random effects probit and conditional logit model: The total number of choice observations were 7731 for each stated preference experiment. Each respondent was shown nine choice sets. 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 moving from long-duration to short-duration and basmati rice varieties. 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 adopting the short-duration and basmati rice variety. Farmers prefer to switch to short-duration and basmati rice variety at higher area-based payment and minimum assured price. They are more likely to stay with the status quo at a lower economic incentive. The standard deviations reflect the heterogeneity of preferences. Statistically significant standard deviations show that respondents value certain aspects to varying degrees. The results are reported in figure 3.4.

Figure 3:4 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	.76077***	.04374
AssurePric_3500	2.3555***	0.0819	1.4101***	.04662
Price_AssurePric_100	-0.0180***	0.0007	-.0102***	.00043
Price_AssurePric_10_HP	-0.3174***	0.0090	-.18426***	.00486
Log likelihood	-2161.5885		-3949.4358	
Pseudo r-squared	0.37		0.25	
const			.18887***	.04433
lnsig2u			-.6824	.0817
sigma_u			.7108	.0290
rho			.3357	.0182
No of observations	7731		7731	

****P<0.05*

In figure 3.4, 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 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* are coefficients for minimum assured price attribute of Rs. 3200 per quintal, Rs. 3500 per quintal, and electricity price attribute of Rs. 100/month and Rs. 10/HP/month for Experiment B respectively.

In Experiment A, the attribute area-based payment exhibits positive and significant effect, which indicates that higher payment has a positive effect on farmers choosing to adopt the short-duration rice variety. Farmers significantly prefer area-based payment of Rs. 4500 per acre over Rs. 4200 per acre and Rs. 4000 per acre for adopting short-duration paddy variety. The coefficients for price of electricity attribute show negative preferences for payment of electricity compared to no electricity charge. The negative price coefficients for Experiment A and Experiment B are lower for monthly electricity tariff. Significant standard deviations indicate heterogeneity among farmers for payment levels and electricity rates. The pseudo R^2 of the model is 0.25, which is a good fit, and the overall model is highly significant.

In Experiment B, the positive significance of the assured price attribute suggests that higher the level of this attribute relative to no minimum assured price for basmati, farmers are more likely to prefer basmati over long-duration rice variety. The negative and significant coefficient for price of electricity attribute suggests that higher the burden of electricity charge relative to no charge on electricity, the lower the willingness to pay/willingness to accept. These results are consistent with a-prior expectation and provide evidence of the theoretical validity of the model. The pseudo R^2 comes to 0.25 which is a good fit, and the overall model is highly significant.

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).

ii) Odds Ratios: Since logistic coefficients represent the change in the log-odds of the occurrence of the dependent variable, these coefficients can be exponentiated to get rid of the log and arrive at Odds Ratio. Odds Ratio represents the change in the odds of the dependent variable associated with a one-unit change in the independent variable.

Figure 3:5 Odds Ratio

Attribute	Odds Ratio	Std. Err.
Experiment A		
Payment_4200	9.5088***	0.79451
Payment_4500	12.0251***	1.0245
Price_Payment_100	0.97758***	0.00083
Price_Payment_10_HP	0.75756***	0.00682
Experiment B		
AssurePric_3200	3.6312***	0.2733
AssurePric_3500	10.544***	0.8641
Price_AssurePric_100	0.9821***	0.0007
Price_AssurePric_10_HP	0.7279***	0.0065
No of observations	7731	

****P<0.05*

The results of the Odds Ratio for Experiment A and Experiment B in figure 3.5 show that the Odds Ratio of adopting the shorter duration rice variety is 12 times higher for area-based payment of Rs. 4500 per acre and 9.5 times higher for payment of Rs. 4200 per acre than for no payment. The Odds Ratio of paying Rs. 10/HP/Month and monthly rate of Rs. 100 is less likely than for no electricity charge in both experiments. The Odds Ratio of adopting basmati rice with minimum assured price of Rs. 3200 per quintal is 3.6 times higher and 10.5 times higher for minimum assured price of Rs. 3500 per quintal than for no minimum assured price.

iii) Willingness to pay/willingness to accept: Another way to look at the results is the willingness to pay/willingness to accept (WTP/WTA) values. WTP/WTA is the marginal rate of substitution between an attribute and the price attribute. In other words, WTP is the compensation value in monetary terms for a one-unit deterioration of an attribute to remain at the same level of utility. WTP/WTA is estimated as the ratio of the value of the coefficient of interest, the economic incentive, to the negative of the price of electricity coefficient to explore the trade-offs. Delta method confidence intervals are calculated using the nlcom command in STATA (Hole 2007).

Figure 3.6 below shows the WTP/WTA estimates, and their corresponding 95% intervals estimated by dividing the coefficient of the incentive attribute with the price coefficient of Rs. 100/month and price coefficient of Rs. 10/HP/Month. This method is repeated for the two levels of area-based payments for short-duration rice and minimum assured prices for basmati rice. The results indicate that respondents' willingness to pay/willingness to accept for each attribute increases with the higher level of the economic incentive.

The WTP/WTA is Rs. 99.46 ($1.24) per month and Rs. 8.38($0.10)/HP/month for Rs. 4200 per acre and Rs. 112 ($1.40) per month and Rs. 9.45($0.11)/HP/month for Rs. 4500 per acre payment for short-duration rice. 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/q and Rs. 137 ($1.73) per month and Rs. 7.65($0.09)/HP/month for Rs. 3500/q minimum assured price for basmati. The similarity of results under logit and probit models suggests a high level of convergent validity between the two models. The WTP/WTA valuations for monthly electricity rate are higher for minimum assured price of basmati and higher for load-based tariff with area-based payment for adopting short-duration rice.

Figure 3:6 Willingness to pay/willingness to accept values

Attribute	Conditional logit	Random effects probit	Conditional logit	Random effects probit
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)

****P<0.05*

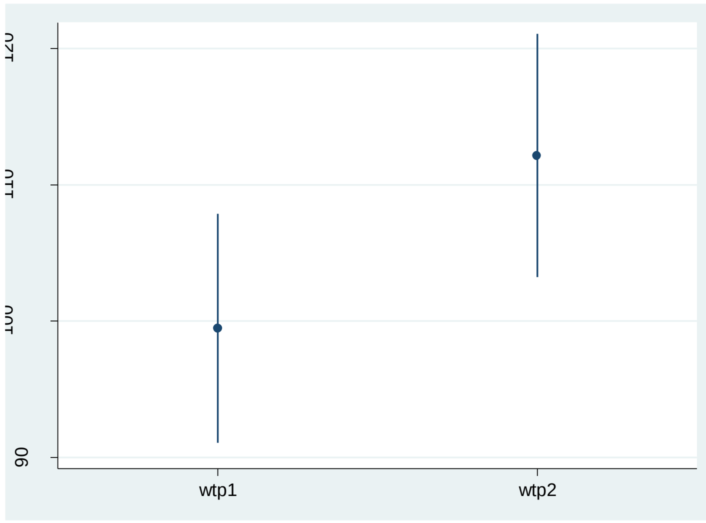


Figure 3:7 Willingness to pay fixed monthly charge and 95% confidence intervals in Experiment A

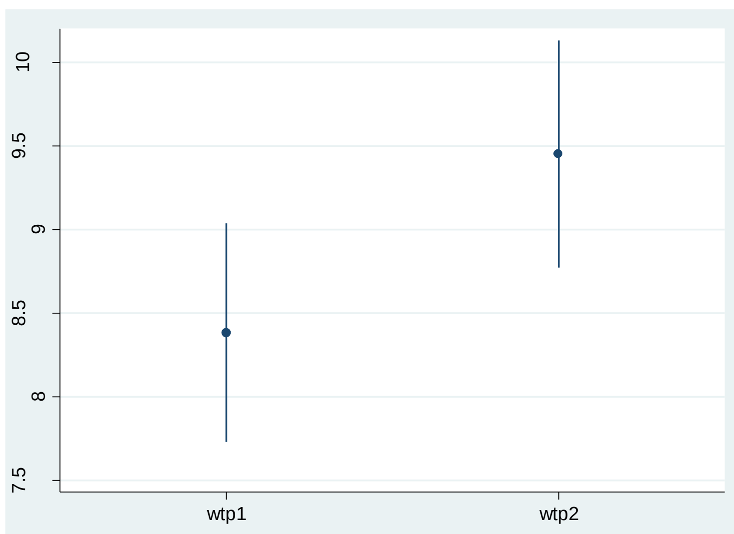


Figure 3:8 Willingness to pay load-based charge and 95% confidence intervals in Experiment A

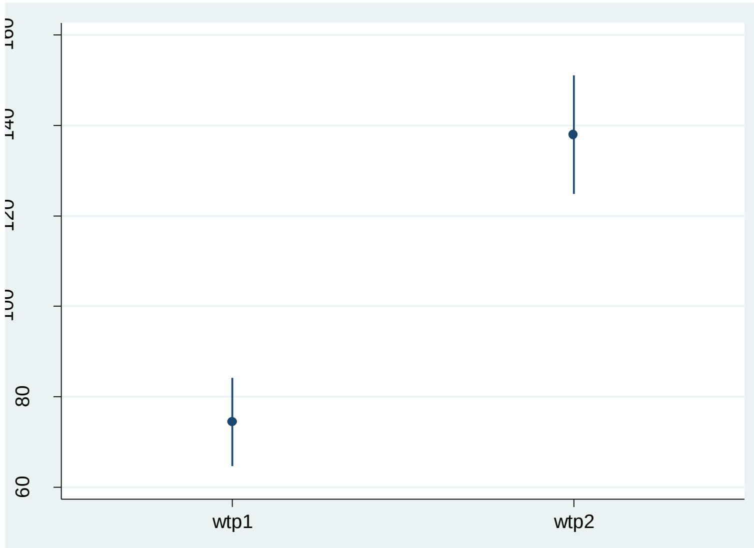


Figure 3:9 Willingness to pay fixed monthly charge and 95% confidence intervals in Experiment B

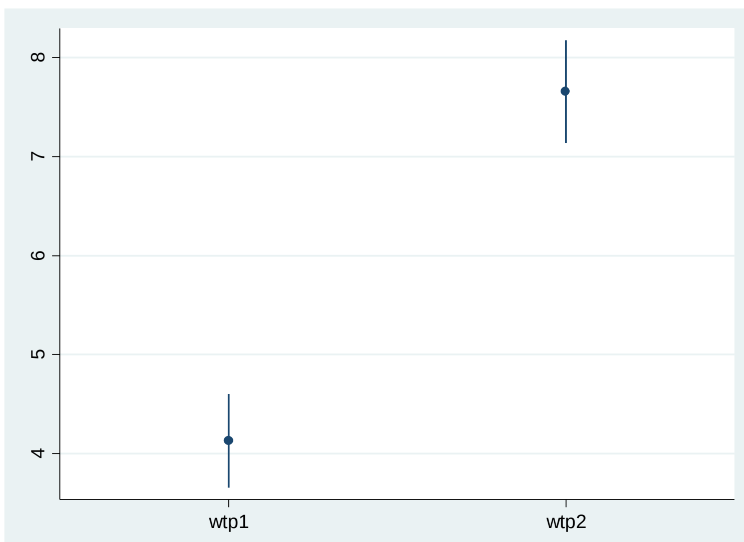


Figure 3:10 Willingness to pay load-based charge and 95% confidence intervals in Experiment B

iv) Marginal effects: Marginal effects are estimated to communicate the economic significance of the results (Bland and Cook, 2019). It is found that area-based payment of Rs. 4500 per acre increases the probability of shifting to short-duration rice by 36 percentage points. The increase in probability of switching to basmati with minimum assured price of Rs.

3500/q is 35 percentage points. The results are displayed in figure 3.11.

Figure 3:11 Marginal effects

Attribute	dydx (Random Effects Probit)	Std. Err.	dydx (Conditional Logit)	Std. Err.
Payment_4200	0.3244***	0.0098	0.3810***	0.0124
Payment_4500	0.3658***	0.0095	0.4207***	0.0121
Price_Payment_100	-0.0032***	0.0000	-0.0038***	0.0001
Price_Payment_10_HP	-0.0387***	0.0008	-0.0469***	0.0010
AssurePric_3200	0.1922***	0.0104	0.2079***	0.0119
AssurePric_3500	0.3564***	0.0094	0.3798***	0.0119
Price_AssurePric_100	-0.0025***	0.0000	-0.0029***	0.0000
Price_AssurePric_10_HP	-0.0465***	0.0008	-0.0511***	0.0006

****P<0.05*

v) 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. The probability of uptake is simulated for the different attribute levels. 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 figure 3.12. 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.

Figure 3:12 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*

Change in probability: By differentiating the probability function with respect to changes in the attribute level, 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). Figure 3.13 presents the impact of the policies. While economic incentive 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 shifting to short-duration rice by 8.3 percentage points. The probability of adoption of basmati increases by 31 percentage points with the increase in minimum assured price from Rs. 3200/quintal to Rs. 3500/quintal. The probability of farmers accepting to pay monthly electricity charge is significantly higher than for load-based electricity tariff.

Figure 3:13 : 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*

vi) Comparison of coefficients between the regions: A comparison of preference behavior between farmers in the three regions of Majha, Malwa and Doaba in Figure 3.14 shows that farmers in the Malwa region are most likely to accept area-based payment for adopting short-duration rice variety. Farmers in the Doaba region comparatively value the higher area-based payment for shifting to short-duration rice variety. Farmers in the Majha region are more favorably inclined towards substituting basmati variety with the offer of minimum assured price. Farmers in the Doaba region have lower negative preferences for willingness to pay for electricity with offer of area-based payment for adopting short-duration rice. Majha region farmers are comparatively more willing to pay for electricity with an offer of minimum assured price for basmati.

Figure 3:14 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*

vii) Non-linear effects through interaction: The nonrandom variation in the parameters can be hypothesized in the econometric model. The importance a farmer attaches to the offer of an economic incentive for adoption of low-water rice variety and payment of electricity charge may be influenced by his education level, land size, tube well ownership and load capacity. Segmentation analysis is conducted to determine the effect of socio-economic and demographic characteristics of farmers on their preferences for the 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 – upto matriculate, upto graduate and beyond graduate. The interaction of the attribute variables with the socio-economic and demographic variables resulted in both significant and non-significant results. Equation 3.13 illustrates the specification of some of the interaction terms.

$$\Delta V = \alpha 3\, x\, Areapayment4200\#Marginal + \alpha 4\, x\, Areapayment4200\#Small + \alpha 5\, x\, Areapayment4200\#Semimedium + \alpha 6\, x\, Areapayment4200\#Medium + \alpha 7\, x\, Areapayment4200\#Large + \alpha 8\, x\, Areapayment4200\#Lowload + \alpha 9\, x\, Areapayment4200\#Mediumload + \alpha 10\, x\, Areapayment4200\#Highload + \alpha 11\, x\, Areapayment4200\#Singlewell + \alpha 12\, x\, Areapayment4200\#Multiplewell \quad (3.13)$$

The results of the interaction terms are shown in figure 3.16 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 tariff 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 basmati rice adoption 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 tariffs 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 adopting basmati rice variety.

3.6: Discussion

Using data from two stated preference experiments with farmers, this study finds empirical evidence of a strong preference for output price support among Punjab farmers for adopting low-water rice varieties. Positive and significant preferences are observed for the attributes of area-based payment for adopting short-duration variety and minimum assured price for growing basmati. Furthermore, farmers are more likely to opt for the status-quo option at the first level of area-based payment and minimum assured price if these are offered in combination with a charge on electricity.

The acceptance rate for the different bundles of economic incentives and electricity charges varies across farmers. As expected, ceteris paribus the acceptance rate increases with higher economic incentive and lower burden of electricity price. It is found that 77 percent of the farmers prefer statistically significant compensation of Rs. 4200 per acre to shift to short-duration rice and 74 percent prefer a minimum assured price of Rs. 3200/q for basmati rice. The coefficients increase significantly with the higher incentive level, suggesting that farmers are sensitive to the magnitude of the incentive for making variety shifts. Results illustrate that economic incentives for shifting to low-water rice can be combined with electricity pricing on a monthly or load-basis, depending on farmers' preferences. The standard deviations show that the respondents value certain aspects to varying degrees. Socioeconomic characteristics are found to be significant determinants governing farmers' preferences.

Significant heterogeneity is found in the valuation for economic incentives combined with electricity pricing. Offering a monthly electricity charge is likely to attract a higher probability of acceptance. The offer of area-based payment of Rs. 4200 per acre and a monthly electricity bill of Rs. 100 is acceptable to 66 percent of the farmers. A higher area-based payment of Rs. 4500 per acre could partly make up for the shift to load-based electricity tariff, with around 55 percent of the farmers willing to accept the scheme. Hence, there is evidence that higher area-based payments can incentivize farmers to pay electricity bills. Similarly, the acceptance rate of shifting to basmati rice is 58 percent with a minimum assured price of Rs. 3200/q and a monthly electricity charge of Rs. 100/month. The higher minimum assured price of Rs. 3500/q with a monthly electricity bill has 66 percent acceptance rate. Minimum assured price combined with load-based tariff 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 incentive payments for low-water rice variety. The negative coefficients for load-based electricity tariffs are higher than for monthly electricity charges. This shows farmers' relative preference for monthly electricity charges.

The main specification of the model allowed the estimation of WTP/WTA. The focus of this research is the monetary amount farmers are willing to pay for electricity if offered an economic incentive to shift to low-water rice variety. The trade-off between free electricity and economic incentive has been estimated. It is found that farmers are willing to sacrifice Rs. 99/month and Rs. 112/month for area-based payments of Rs. 4200 per acre and Rs. 4500 per acre respectively. Farmers are willing to sacrifice Rs. 74/month for Rs. 3200/q and Rs. 137/month for a minimum assured price of Rs. 3500/q for basmati rice. These findings can shed light on the trade-offs farmers are willing to make for assured output price support for low-water rice varieties. Policymakers could use this information to encourage payment behavior while designing compensation schemes.

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

This study provides empirical evidence that no farmer is likely to adopt the low-water rice variety unless there is some economic benefit. 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 shifting to less water and energy-intensive rice varieties. Currently, the government is spending $747.2 million (2018-19) on free electricity for agriculture. Repackaging the input subsidy as output price support can contribute significantly to financing the incentive 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.

A simple cost-benefit analysis is presented in figure 3.15 to understand the implications of substituting short-duration rice variety on 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 varieties. The cost of disbursing an incentive of Rs. 4200 per acre on adopting PR 126 would be $41.04 million. Electricity subsidy savings are calculated based on two criteria – the daily cost of pumping estimated by the utility and optimal irrigation water requirement for different crops estimated by the Punjab Agriculture University. The savings from electricity subsidy would be $55.5 million based on the cost of daily four hours of pumping estimated by the utility and $14 million based on the irrigation requirement of different rice varieties determined by the Punjab Agriculture University. As there is the likelihood of farmers overusing water, hence the subsidy savings based on the daily 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. The revenue from the monthly electricity charge could generate $2.01 million for the utility.

Figure 3:15 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 tubewells***	number	133600
Annual electricity tariff from each tubewell	$	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 incentive could be partly borne out of the subsidy savings on electricity and partly by diverting some unproductive input subsidies. Further, it has been suggested that the opportunity cost of diverting irrigation water for meeting human needs in water deficit areas of the country was Rs. 0.4 (Johl and Singh, 2017). Advancing this suggestion, the revenue from the sale of water could be around $547 million, if the irrigation water saved is diverted for meeting drinking water needs in water deficit areas.

Some input subsidies are perceived as unproductive and ineffective by the farmers. For instance, the Punjab government disburses subsidies on a range of agricultural machinery, which could be diverted to pay incentives on output prices to induce crop shifts. Respondent farmers showed their dissatisfaction concerning the subsidy provided for the purchase of agriculture machinery in Punjab. 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. Subsidies on big agriculture machinery are considered more beneficial for large farmers (Anand and Kaur, 2019). These could be channelized towards offering output price support to low-water crops for wider coverage of all farmers.

An important finding of this study is that stability of the incentive and electricity tariff rates over the medium term would encourage adoption decisions. It is found that farmers are quality conscious and willing to pay a price to get better quality of supply. A potentially promising area 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 in reducing energy use in Indian agriculture (Kimmich and Sagebiel, 2016). Further, Punjab farmers are not particularly keen on receiving low-quality free electricity; reliable and stable farm power is rated higher than free farm power.

3.7: Conclusion

An increase in expected returns from low-water rice varieties 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 grow low-water crops which slow down water depletion, reduce electricity consumption, and lower 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 that drive rice variety adoption decisions of farmers. The econometric estimation analyzed farmers' valuations for economic incentives to make variety shifts and acceptability of different levels of economic incentives and electricity rates. Random effects probit and conditional logit models took account of the heterogeneity of preferences for area-based payments for short-duration rice and minimum assured price for basmati rice. It is found that there is a significant valuation for most of the incentive attribute levels, suggesting that compensation at fairly moderate levels could be offered to induce shifts to low-water rice varieties and encourage the willingness to pay for electricity. The discrete choice methodology allowed the estimation of WTP/WTA and evaluation of possible pricing strategies that could incentivize the participation of the 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 tariffs could encourage farmers' willingness to pay.

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

The WTP/WTA 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 payment for short-duration rice. WTP/WTA is Rs. 8.3(0.10)/HP/month for Rs. 4200 per acre payment and Rs. 9.45(0.11)/HP/month for Rs. 4500 per acre payment for short-duration rice. The WTP/WTA is Rs. 74.4 ($0.93) per month for the minimum assured price of Rs. 3200/q and Rs. 137.96 ($1.73) per month for Rs. 3500/q for basmati. The WTP/WTA value 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/WTA values are adequately high given the levels of satisfaction with the quality of electricity supply. However, improvements in the reliability of electricity cannot be financed by increasing electricity tariffs without reducing social welfare.

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 behavior. Some farmers may have a higher willingness to pay and identifying them provides scope for introducing reform. Matriculate farmers are more likely to pay electricity bills with the offer of area-based payment and minimum assured price. Marginal farmers, medium farmers, and multiple tube well-owning farmers are likely to prefer load-based tariffs with area-based payment. Farmers in the Malwa region are more likely to accept area-based payment for adopting 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.

The chapter 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 nexus in India. Future work could explore heterogeneity in farmers' preferences for different crop varieties and willingness to pay for electricity. Consideration of attribute interactions could be an interesting extension of this work. The findings of this chapter 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 behavior, policy, and preferences in the future.

References

Abokyi, E., Strijker, D., Asiedu, K. F., & Daams, M. N. (2020). The impact of output price support on smallholder farmers' income: evidence from maize farmers in Ghana. Heliyon, 6(9), 1-13.

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. Agricultural economics, 13(1), 1-9.

Aggarwal, R., Kaushal, M., Kaur, S., & Farmaha, B. (2009). Water resource management for sustainable agriculture in Punjab, India. Water Science and Technology, 60(11), 2905-2911.

Akber, N. (2020). Does input subsidy discourage public investment in Indian agriculture? Evidence from ARDL applications. Journal of Public Affairs, 22(2), 1-12.

Anand, A., & Kaur, M. (2019). Perspective of economists and extension personnel towards agricultural subsidies in Punjab. Economic Affairs, 64(1), 41-46.

Asrat, S., Yesuf, M., Carlsson, F., & Wale, E. (2010). Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. Ecological Economics, 69(12), 2394-2401.

Badiani, R., Jessoe, K. K., & Plant, S. (2012). Development and the environment: the implications of agricultural electricity subsidies in India. The Journal of Environment & Development, 21(2), 244-262.

Bayes, A. M., Parton, K. A., & Piggott, R. R. (1985). Combined price support and fertilizer subsidy policies for food self-sufficiency: A case study of rice in Bangladesh. Food Policy, 10(3), 225-236.

Barrowclough, M. J., & Alwang, J. (2018). Conservation agriculture in Ecuador's highlands: a discrete choice experiment. Environment, Development and Sustainability, 20(6), 2681-2705.

Bhattarai, N., Pollack, A., Lobell, D. B., Fishman, R., Singh, B., Dar, A., & Jain, M. (2021). The impact of groundwater depletion on agricultural production in India. Environmental Research Letters, 16(8), 1-14.

Bland, J. R., & Cook, A. C. (2019). Random effects probit and logit: understanding predictions and marginal effects. Applied Economics Letters, 26(2), 116-123.

Boardman, J., Poesen, J., & Evans, R. (2003). Socio-economic factors in soil erosion and conservation. Environmental Science & Policy, 6(1), 1-6.

Bopp, C., Engler, A., Poortvliet, P. M., & Jara-Rojas, R. (2019). The role of farmers' intrinsic motivation in the effectiveness of policy incentives to promote sustainable agricultural practices. Journal of Environmental Management, 244, 320-327.

Brar A.S, (2021) Performance of multiple cropping systems vis-à-vis rice wheat under different methods of irrigation, Punjab Agriculture University, Ludhiana. Unpublished.

Breustedt, G., Müller-Scheeßel, J., & Latacz-Lohmann, U. (2008). Forecasting the adoption of GM oilseed rape: Evidence from a discrete choice experiment in Germany. Journal of Agricultural Economics, 59(2), 237-256.

Brownstone, D., & Small, K. A. (2005). Valuing time and reliability: assessing the evidence from road pricing demonstrations. Transportation research part a: policy and practice, 39(4), 279-293.

Campbell, G. E. (1989). Landowner characteristics, attitudes, and opinions toward producing biomass for energy feedstocks on marginal land in the Great Lakes region, USA. Biomass, 19(4), 307-322.

Chang, J. B., Lusk, J. L., & Norwood, F. B. (2009). How closely do hypothetical surveys and laboratory experiments predict field behavior?. American Journal of Agricultural Economics, 91(2), 518-534.

Cox, C. (2006). US Agriculture conservation policy and programs: History, trends, and implications. US Agricultural Policy and the 2007 Farm Bill, 113-146.

Cummings Jr, R., Rashid, S., & Gulati, A. (2006). Grain price stabilization experiences in Asia: What have we learned?. Food Policy, 31(4), 302-312.

Czajkowski, M., Zagórska, K., Letki, N., Tryjanowski, P., & Wąs, A. (2021). Drivers of farmers' willingness to adopt extensive farming practices in a globally important bird area. Land Use Policy, 107, 1-13.

Demirdogen, A., Olhan, E., & Hasdemir, M. (2021). Heterogeneous impact of agricultural support policies: evidence from Turkey. Environment, Development and Sustainability, 1-23.

De Fraiture, C., & Perry, C. (2002, June). Why is irrigation water demand inelastic at low price ranges. In conference on irrigation water policies: micro and macro considerations (pp. 15-17).

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global environmental Change, 19(2), 248-255.

Fang, C. (2010). How China stabilized grain prices during the global crisis. The rice crisis: Markets, policies and food security, Routledge. 255-272.

Fosli, J. K., Reddy, A. A., & Rani, R. (2021). The policy of free electricity to agriculture sector: implications and perspectives of the stakeholders in India. Journal of Development Policy and Practice, 6(2), 252-269.

Gautam, M. (2015). Agricultural subsidies: Resurging interest in a perennial debate. Indian Journal of Agricultural Economics, 70(1) (2015), 83-105.

Gbetibouo, G. A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. Discussion paper (Vol. 849). International Food Policy Research Institute.

Gohain, N., & Singh, S. (2018). An analysis of problems and constraints faced by farmers in marketing of agricultural produce in Punjab. Economic Affairs, 63(3), 671-678

Grover, D. K. (2012). Basmati rice cultivation for resource conservation and use efficiency in context of sustainable agriculture in Punjab. Indian Journal of Economics and Development, 8(2), 11-26.

Gulati, A., & Sharma, A. (1995). Subsidy syndrome in Indian agriculture. Economic and Political Weekly, A93-A102.

Haghani, M., Bliemer, M. C., Rose, J. M., Oppewal, H., & Lancsar, E. (2021). Hypothetical bias in stated choice experiments: Part II. Conceptualisation of external validity, sources and explanations of bias and effectiveness of mitigation methods. Journal of choice modelling, 41, 100322

Hindustan Times (2022), PR 126 paddy variety can save up to 7 bl cubic metres water in Punjab: PAU research, https://www.hindustantimes.com/cities/chandigarh-news/pr-126-paddy-variety-can-save-up-to-7-bl-cubic-metres-water-in-punjab-pau-research-101652468479267.html, 14.05.22

Hole, A. R. (2007). A comparison of approaches to estimating confidence intervals for willingness to pay measures. Health economics, 16(8), 827-840.

Hubbell, B. J., Marra, M. C., & Carlson, G. A. (2000). Estimating the demand for a new technology: Bt cotton and insecticide policies. American Journal of Agricultural Economics, 82(1), 118-132.

Indian Express (2021), In 11 Punjab districts, farmers who cultivate maize instead of paddy to get financial aid https://indianexpress.com/article/cities/ludhiana/in-11-punjab-districts-farmers-who-cultivate-maize-instead-of-paddy-to-get-financial-aid-7242290/, 24.03.21.

Jaffe, J. (1989). Land use, soil degradation, and farmer decision-making: a Sondeo report of Cavalier, Despa, Kols, and Saut Mathurine, Haiti. Port-au-Prince, Haiti. Available online: http://dlc.dlib.indiana.edu/ dlc/handle/10535/4152.

Jensen, K., Clark, C. D., Ellis, P., English, B., Menard, J., Walsh, M., & de la Torre Ugarte, D. (2007). Farmer willingness to grow switchgrass for energy production. Biomass and Bioenergy, 31(11-12), 773-781.

Jha, B., Mohanty, B., & Tripathi, A. (2009). Drivers of agricultural diversification in India, Haryana and the greenbelt farms of India. Working Paper Series No. 303, Institute of Economic Growth, University Of Delhi Enclave.

Jaeck, M., & Lifran, R. (2014). Farmers' preferences for production practices: a choice experiment study in the Rhone river delta. Journal of Agricultural Economics, 65(1), 112-130.

Jin, S., Mansaray, B., Jin, X., & Li, H. (2020). Farmers' preferences for attributes of rice varieties in Sierra Leone. Food Security, 12(5), 1185-1197.

Johl, S. S., Sidhu, R. S., & Vatta, K. (2014). Natural resources management in Punjab agriculture: challenges and way forward. Discussion Paper, Centre for International Projects Trust. New Delhi.

Johl, SS and Singh I M (2017), From water deficit to surplus, The Tribune, 30 June 2017.

Johansson-Stenman, O., & Svedsäter, H. (2012). Self-image and valuation of moral goods: Stated versus actual willingness to pay. Journal of Economic Behavior & Organization, 84(3), 879-891.

Joshi, K.; Joshi, P.K.; Khan, M.T.; Kishore, A. 'Sticky Rice': Variety inertia and groundwater crisis in a technologically progressive state of India. In IFPRI Discuss; Paper 01766; International Food Policy Research Institute: Washington, DC, USA, 2018. Available online: http://ebrary.ifpri.org/cdm/singleitem/collection/p15738coll2/id/132924

Kannan, E. (2014). Farm input subsidies in India: Access, efficiency and equity. In International Association of Agricultural Economists symposium on Revisiting Agriculture Policies in the Light of Globalisation Experience: The Indian Context. MANAGE, Hyderabad, India.

Kimmich, C., & Sagebiel, J. (2016). Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture. Utilities Policy, 43, 174-185.

Kishore, A., & Verma, S. (2003). What determines pumping behaviour of tubewell owners: marginal cost or opportunity cost?.

Kolady, D. E., & Lesser, W. (2006). Who adopts what kind of technologies? The case of Bt eggplant in India. AgBioForum, 9(2), 94-103.

Krishijagran (2020), Mera Pani Meri Virasat Scheme: Farmers opting for non-paddy crops to get Rs. 7000 per acre, https://krishijagran.com/agriculture-world/mera-pani-meri-virasat-scheme- farmers-opting-for-non-paddy-crops-to-get-rs-7000-per-acre/, 07.05.22.

Krishna, V. V., & Qaim, M. (2007). Estimating the adoption of Bt eggplant in India: who benefits from public–private partnership?. Food Policy, 32(5-6), 523-543.

Liancui, W., & Honghui, C. (2010). Positive study on the effect of grain subsidy policy on farmers’ planting behavior. Technology Economics, 6, 68-73.

Krishijagran (2020), Mera Pani Meri Virasat Scheme: Farmers opting for non-paddy crops to get Rs. 7000 per acre, https://krishijagran.com/agriculture-world/mera-pani-meri-virasat-scheme-farmers-opting-for-non-paddy-crops-to-get-rs-7000-per-acre/, 07.05.22.

Krishna, V. V., & Qaim, M. (2007). Estimating the adoption of Bt eggplant in India: who benefits from public–private partnership?. Food Policy, 32(5-6), 523-543.

Liancui, W., & Honghui, C. (2010). Positive study on the effect of grain subsidy policy on farmers’ planting behavior. Technology Economics, 6, 68-73.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: analysis and applications. Cambridge University Press.

Lusk, J. L., & Schroeder, T. C. (2004). Are choice experiments incentive compatible? A test with quality differentiated beef steaks. American journal of agricultural economics, 86(2), 467-482.

Manan, J., Sharma, M., & Jaidka, M. (2018). Factors affecting the adoption of paddy varieties in Kapurthala district of Punjab, India. International Journal Current Microbiology and Applied Science, 7(9), 3014-3020.

Mehdi, B., Lehner, B., & Ludwig, R. (2018). Modelling crop land use change derived from influencing factors selected and ranked by farmers in North temperate agricultural regions. Science of the Total Environment, 631, 407-420.

Mørkbak, M. R., Olsen, S. B., & Campbell, D. (2014). Behavioral implications of providing real incentives in stated choice experiments. Journal of Economic Psychology, 45, 102-116.

Mehdi, B., Lehner, B., & Ludwig, R. (2018). Modelling crop land use change derived from influencing factors selected and ranked by farmers in North temperate agricultural regions. Science of the Total Environment, 631, 407-420.

Mørkbak, M. R., Olsen, S. B., & Campbell, D. (2014). Behavioral implications of providing real incentives in stated choice experiments. Journal of Economic Psychology, 45, 102-116.

Molle, F. (2003). Development trajectories of river basins: A conceptual framework (Vol. 72). International Water Management Institute.

Mukherji, A., & Das, A. (2014). The political economy of metering agricultural tube wells in West Bengal, India. Water international, 39(5), 671-685.

Nehring, R. F. (1991). Output and Input Subsidy Policy Options in Bangladesh. Journal of Agricultural Economics Research, 43(2), 29-41.

Punjab Agriculture University (2022), Package of practices for crops of Punjab Kharif 2022, Punjab Agriculture University.

Paulrud, S., & Laitila, T. (2010). Farmers' attitudes about growing energy crops: a choice experiment approach. Biomass and Bioenergy, 34(12), 1770-1779.

Purola, T., & Lehtonen, H. (2022). Farm-level effects of emissions tax and adjustable drainage on peatlands. Environmental Management, 69(1), 154-168.

Qaim, M., & De Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: the case of Bt cotton in Argentina. American Journal of Agricultural Economics, 85(4), 814-828.

Ostwald, M., Jonsson, A., Wibeck, V., & Asplund, T. (2013). Mapping energy crop cultivation and identifying motivational factors among Swedish farmers. Biomass and Bioenergy, 50, 25-34.

Parish, R. M., & McLaren, K. R. (1982). Relative cost-effectiveness of input and output subsidies. Australian Journal of Agricultural Economics, 26(1), 1-13.

Rahmani, M., Hodges, A. W., & Stricker, J. A. (1996). Potential producers and their attitudes toward adoption of biomass crops in Central Florida. In Proceedings of the 7th National Bio Energy Conference, Nashville, TN, 671-678.

Ray, I., & Gül, S. (1999). More from less: policy options and farmer choice under water scarcity. Irrigation and Drainage Systems, 13(4), 361-383.

Repetto, R. (1987). Economic incentives for sustainable production. The Annals of Regional Science, 21(3), 44-59.

Rizov, M., Pokrivcak, J., & Ciaian, P. (2013). CAP subsidies and productivity of the EU farms. Journal of Agricultural Economics, 64(3), 537-557.

Ruto, E., & Garrod, G. (2009). Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach. Journal of Environmental Planning and Management, 52(5), 631-647.

Ryan, M., Kolstad, J. R., Rockers, P. C., & Dolea, C. (2012). How to conduct a discrete choice experiment for health workforce recruitment and retention in remote and rural areas: a user guide with case studies (No. 74489, pp. 1-94). The World Bank.

Ryan, M., & Hughes, J. (1997). Using conjoint analysis to assess women's preferences for miscarriage management. Health Economics, 6(3), 261-273.

Ryan, M., & Gerard, K. (2003). Using discrete choice experiments to value health care programmes: current practice and future research reflections. Applied Health Economics and Health Policy, 2(1), 55-64.

Sattler, C. & Nagel, U.J., 2010. Factors affecting farmers' acceptance of conservation measures – a case study from North-Eastern Germany. Land Use Policy 27, 70–77.

Sayre, S. S., & Taraz, V. (2019). Groundwater depletion in India: Social losses from costly well deepening. Journal of Environmental Economics and Management, 93, 85-100.

Sckokai, P., & Moro, D. (2006). Modeling the reforms of the common agricultural policy for arable crops under uncertainty. American Journal of Agricultural Economics, 88(1), 43-56.

Schulz, N., Breustedt, G., & Latacz-Lohmann, U. (2014). Assessing farmers' willingness to accept "greening": Insights from a discrete choice experiment in Germany. Journal of Agricultural Economics, 65(1), 26-48.

Siyaranamual, M., Amalia, M., Yusuf, A., & Alisjahbana, A. (2020). Consumers' willingness to pay for electricity service attributes: A discrete choice experiment in urban Indonesia. Energy Reports, 6, 562-571.

Shittu, A. M., Kehinde, M. O., Ogunnaike, M. G., & Oyawole, F. P. (2018). Effects of land tenure and property rights on farm households' willingness to accept incentives to invest in measures to combat land degradation in Nigeria. Agricultural and Resource Economics Review, 47(2), 357-387.

Sidhu, B. S., Kandlikar, M., & Ramankutty, N. (2020). Power tariffs for groundwater irrigation in India: A comparative analysis of the environmental, equity, and economic tradeoffs. World Development, 128, 104836, 1-13.

Silvano, R. A., Udvardy, S., Ceroni, M., & Farley, J. (2005). An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management. Ecological Economics, 53(3), 369-385.

Singh, A. K., S. Gopala Krishnan, M. Nagarajan, K. Vinod, P. Bhowmick, S. Atwal, R. Seth et al. Variety Pusa Basmati 1509. Indian Journal of Genetics and Plant Breeding 74 (2014): 123-123.

Singh, J. M., Sachdeva, J., Bhangu, P. K. S., Singh, J., Kaur, B., & Kumar, H. (2022). Groundwater Saving in Punjab: Role of Short-duration Paddy Varieties in Agricultural Sustainability. Indian Journal of Ecology, 49(2), 358-362.

Singh, V., Singh, A. K., Mohapatra, T., & Ellur, R. K. (2018). Pusa Basmati 1121–a rice variety with exceptional kernel elongation and volume expansion after cooking. Rice, 11, 1-10.

Statistics of Punjab Agriculture (2020), Punjab Agricultural University, Ludhiana.

The Tribune (2022a), Haryana announces Rs 4,000 per acre incentive for farmers using new paddy sowing method https://www.tribuneindia.com/news/haryana/haryana-announces-rs-4-000-per-acre-incentive-for-farmers-using-new-paddy-sowing-method-395975, 18.05.22.

The Tribune (2022b), Rs 4,000 per acre for farmers growing pulses, oilseeds in Haryana's seven districts

https://www.tribuneindia.com/news/haryana/rs-4-000-per-acre-for-farmers-growing-pulses-oilseeds-in-haryanas-seven-districts-409152, 03.07.22

Wade, T., Claassen, R., & Wallander, S. (2015). Conservation-practice adoption rates vary widely by crop and region United States Department of Agriculture, Economic Research Service: Washington, DC, USA, 1-34.

Ward, P., Ortega, D., Spielman, D. J., & Singh, V. (2013). Farmer preferences for drought tolerance in hybrid versus inbred rice: Evidence from Bihar, India. International Food Policy Research Institute Discussion Paper, IFPRI Washington DC: CGIAR Research Program on Policies, Institutions and Markets.

Wei, Y. P., White, R. E., Chen, D., Davidson, B. A., & Zhang, J. B. (2007). Farmers' perception of sustainability for crop production on the north China plain. Journal of Sustainable Agriculture, 30(3), 129-147.

Figure 3:16 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*

Questionnaire 1

<table>
<tr><td colspan="2">Village</td><td colspan="2">Block</td><td colspan="2">District</td></tr>
<tr><td colspan="2">Name</td><td colspan="2">Age</td><td colspan="2">Sex</td></tr>
<tr><td colspan="3">Education</td><td colspan="3">Mobile</td></tr>
<tr><td colspan="3">Land owned</td><td colspan="3">Land on lease</td></tr>
<tr><td colspan="6">Land irrigated</td></tr>
<tr><td colspan="6">Non agricultural income</td></tr>
<tr><td colspan="3">Tube owned owned
a. 0
b. 1
c. 2
d. 3
e. Don’t know</td><td colspan="3">Capacity of tube well
a. 5 HP
b. 7.5 HP
c. 10 HP
d. 15 HP
e. 15 HP></td></tr>
<tr><td colspan="3">Do you use diesel pump</td><td colspan="3">No of liters of diesel used in last paddy season
a. 0-50
b. 50-100
c. 100>
d. Don’t know</td></tr>
</table>

Introduction

Sukhgeet Kaur is conducting research in the University about bringing suitable reforms in agriculture. You are aware that a major problem is groundwater depletion in Punjab. Future generations will not get adequate water if this problem is not addressed on priority. Burden of free electricity to agriculture is increasing on the government. The government is already under debt and as a result is not able to make adequate budgetary allocations for health, education etc., The youth of Punjab are facing huge difficulties. They are deprived of good quality of education and not are not able to get good jobs. Drug addiction is rapidly increasing among youth. There is urgent need to find solutions. Experts recommend switch to electricity pricing, like before to save water and energy. The purpose of this survey is to ascertain your views about saving water and electricity. You are at liberty to say yes or no to the survey questions. Your responses will only be used for the research and will not be shared with anyone.

Pusa 44 is water and input intensive, but gives higher returns compared to PR 121/126 rice. These short duration rice varieties consume less water, though on average give 2 quintal/acre lower yield.

1 Would you accept Rs. 4000 per acre for adopting PR121/126 rice variety?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

2 If government offers Rs. 4000 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

3 If government offers Rs. 4000 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

4 Would you accept Rs. 4200 per acre for adopting PR121/126 rice variety?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

5 If government offers Rs. 4200 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

6. If government offers Rs. 4200 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

7. Would you accept Rs. 4500 per acre for adopting PR121/126 rice variety?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

8 If government offers Rs. 4500 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

9 If government offers Rs. 4500 per acre for adopting PR121/126 rice variety and requires you to pay electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

10_How much electric charge would you be willing to pay without any economic incentive for variety change? Tick one

(a) No Bill

(b) Rs. 10/HP/Month

(c) Rs. 20/HP/Month

(d) Rs. 100/Month

11 How much area based payment would you be willing to accept to adopt PR 121/126 rice? There would no electric charge Tick one

(a) No

(b) Rs. 3000 per month

(c) Rs. 3500 per month

(d) Rs. 4000 per month

12. If you consider electric charge of Rs. 100/month high, how much electric charge would you be willing to pay for receiving economic incentive of Rs. 4000/acre, Rs. 4200/acre or Rs. 4500/acre for variety change?
Answer

13.If you consider electric charge of Rs. 10/HP/month high, how much electric charge would you be willing to pay for receiving economic incentive of Rs. 4000/acre, Rs. 4200/acre or Rs. 4500/acre for variety change?
Answer

Questionnaire 2

Instead of growing Pusa 44, you can grow Basamti rice which consumes less water and inputs. However you may not be able to get remunerative price for basmati at times.

1. If the government assures to pay the price difference for basmati in case you receive less than Rs. 3000 per quintal, would you prefer to switch to basmati rice?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

2. If government assures to pay price difference in case you receive less than Rs. 3000 per quintal. However, the government also levies electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

3 If government assures to pay price difference in case you receive less than Rs. 3000 per quintal. However, the government also levies electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

4 If the government assures to pay the price difference for basmati in case you receive less than Rs. 3200 per quintal, would you prefer to switch to basmati rice?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

5 If government assures to pay price difference in case you receive less than Rs. 3200 per quintal.

However, the government also levies electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

6 If government assures to pay price difference in case you receive less than Rs. 3200 per quintal. However, the government also levies electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

7. If the government assures to pay the price difference for basmati in case you receive less than Rs. 3500 per quintal, would you prefer to switch to basmati rice?
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

8 If government assures to pay price difference in case you receive less than Rs. 3500 per quintal. However, the government also levies electric charge of Rs. 100/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

9. If government assures to pay price difference in case you receive less than Rs. 3500 per quintal. However, the government also levies electric charge of Rs. 10/HP/month, would you accept such a scheme? According to our estimate, you would not suffer a loss with such a scheme.
Yes or No

Or would you prefer to grow Pusa 44 rice?
Yes or No

10 If you consider electric charge of Rs. 100/month as high, how much would you be willing to pay to receive Rs. 3000/q, Rs. 3200/q and Rs. 3500/q minimum assured price for basmati?
Answer

11 If you consider electric charge of Rs. 10/HP/month as high, how much would you be willing to pay to receive Rs. 3000/q, Rs. 3200/q and Rs. 3500/q minimum assured price for basmati?
Answer

12 What minimum assured price would you be willing to accept to adopt basmati rice? There would no electric charge. Tick one

(a) Rs. 2500/q

(b) Rs. 2800/q

(c) Rs. 3000/q

13 In your opinion, should the government divert the subsidy on agriculture machinery for providing better output prices?
Answer

4. Chapter: Using rewards and penalties to incentivize energy saving behavior in agriculture – Evidence from a choice experiment in Punjab

4.1: Introduction

The Indian government has historically played a leading role in providing for the energy needs of the nation. With the formation of State Electricity Boards in the early 1950s, power generation picked up significantly (Tongia 2003). Subsidies in electricity, particularly in agriculture became widespread under state-controlled electricity provision. Over time, the free supply of electricity to agriculture has engendered resource use inefficiency and financially weak utilities (Badiani and Jessoe, 2013). Subsidies also hobble utilities' efforts to recover the cost of supply and generate resources required to sustain good service and improve quality (Komives et al., 2005). Further, seen as a lifeline during the Green Revolution in expanding irrigation access, free farm power has encouraged the overexploitation of groundwater even in water-scarce areas (Fosli et al., 2021). Withdrawal of subsidies seems difficult as free farm power has a high political value. Despite huge fiscal costs, governments are reticent to undertake policy reversal for fear of losing popularity (Gulati and Pahuja, 2015). In this context, consumers themselves can be the main stakeholders in achieving sustainable goals. Strategies that can incentivize consumers to minimize consumption and voluntarily curb wasteful behavior have more potential in encouraging sustainable resource use.

There is rich evidence of the use of incentives as a tool to promote environmentally significant decisions and behavior among consumers (Mahmoodi et al., 2021). Studies have found that the implementation of effective tariff designs can help to motivate consumers to reduce consumption and thereby promote energy savings. The concept of loss aversion explains that people react more strongly to penalties than to rewards and go to lengths to avoid losses (Kahneman and Tversky, 1979). Consumers have been found to prefer tariffs that reward decreases in consumption to tariffs that penalize increases in consumption (Mahmoodi et al., 2018). It is recognized that there is a greater need for a more contextualized perspective, whereby losses sometimes loom larger than gains, sometimes losses and gains have a similar psychological impact, and sometimes gains loom larger than losses (Gal and Rucker, 2018). Therefore, understanding consumers' preferences and needs is important in the successful design and implementation of incentives and penalties for promoting energy-saving behavior.

Drawing insights from behavioral economics and recent energy-saving behavior literature, this study examines the effect of a combination of incentives and penalizing tariffs on reducing electricity consumption in agriculture in an Indian State characterized by large and pervasive electricity subsidies. The study also examines whether consumers would prefer to voluntarily subscribe to an annual limit of free electricity units instead of unmetered subsidized electricity as a method to curtail energy use and promote savings. The rationale for this study is that aligning tariff structures more closely with farmers' preferences is likely to reduce the barriers to accepting electricity pricing and conserving natural resources, which face imminent danger with the present pattern of crop choices and electricity consumption in Punjab. The analysis relies upon a stated-preference experiment, which is the most appropriate method to investigate preferences for proposed policy interventions.

This paper is organized in six sections: Section 4.2 presents a description of the problem. Section 4.3 reviews the relevant literature. Section 4.4 discusses the discrete choice methodology applied in this chapter. Section 4.5 contains the empirical results. Section 4.6 discusses the results and policy implications, and Section 4.7 offers conclusions.

4.2: Description of problem

Making electricity services financially viable and recovering the cost of service has long been the core objective of power sector reform in developing countries (Huenteler et al., 2020). Electricity Act 2003 advocates a return to metering to reduce subsidies and improve the financial health of state-owned electricity utilities in India. There are valid reasons for this prescription. Free electricity is a financial drag on fiscal resources. Agriculture electricity subsidies were more than double the national expenditure on health or rural development in 2002. Revenue lost from the electricity sector amounted to a quarter of the national fiscal deficit in 2002 (Badiani and Jessoe, 2013). In India, annual subsidies for agriculture power increased from 4.4 billion nominal USD in 1996 to 11.4 billion nominal USD in 2013 (Planning Commission 2014).

In the prominent agricultural north Indian state of Punjab, the policy of free and unmetered supply of electricity to agriculture has introduced severe distortions in the energy and water sector. There is no check on the use, misuse, and wastage of water from tube wells or agricultural pumps (Johl et al., 2014). The distorted incentive structure has trapped the stakeholders in a conundrum. Farmers are unwilling to relinquish access to free power, economize on usage and shift cropping patterns to low-water crops. Successive governments fear the huge political costs of subsidy withdrawal. Free electricity undermines energy accounting and financial discipline in the utility. Punjab State Power Corporation Limited remains dependent on the Punjab government for subsidy payments. The annual power subsidy bill was more than 10 percent of the State's total budget, of which 40 percent were past arrears on account of the government's failure to pay full subsidy for the past seven years (Hindustan Times 2021).

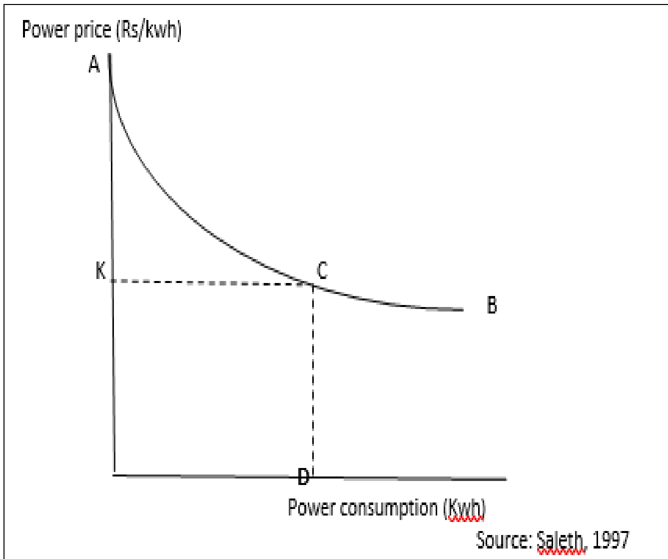
There is mounting evidence that electricity subsidies are detrimental to economic, environmental, and social sustainability. Several issues arise due to subsidies, including electricity leakage because of lack of meters/theft, a rise in consumer size which increases the subsidy burden, and poor revenue generation that reduces the long-term interest of utilities (Bhattacharyya 2012). The unmetered and unverifiable agricultural power supply was regarded as the prime cause of bankruptcy of state electricity boards in India (Shah et al., 2004). Delayed reimbursement payment impairs financial discipline and creates cash-flow issues for the utility. Loss-making utilities are unable to invest in new generation capacity and maintain infrastructure (Shah et al., 2012). This perpetuates a vicious circle as power remains free and quality poor (Blankenship et al., 2019). In addition, there is inequality in the distribution of subsidies to different farm size groups (Singh 2012). The most damaging impact of electricity subsidies on agriculture is that increasing groundwater over-extraction imposes an unintended and long-term environmental cost. Electricity subsidies increase groundwater extraction, where the estimated elasticity is -0.13 (Badiani and Jessoe, 2013). The subsidy-induced increase in groundwater extraction increases the yields of water-intensive crops, thereby incentivizing the replacement of other crops with water-intensive crops thus leading to an increase in the area of such crops.

Another severe implication of unmetered consumption is the camouflaging of inefficiency and theft of electricity. Unmetered consumption may involve excess subsidy transfers. Substantial theft is linked to unmetered electricity use by farmers (Golden and Min, 2012). Bhatia (2007) found that the actual subsidies were only about one-half of those currently estimated. About 33 percent of the estimated sales to agriculture were commercial losses wrongly attributed to agricultural consumption (Gulati and Pahuja, 2012). Manipulation of data by utilities is rampant; discrepancies in the number of installed electric pumps were found in the data reported by different departments of the same power utility in Karnataka (Rawat and Mukherji, 2014); 35 percent higher consumption of agriculture than actual consumption was reported in Uttar Pradesh; technical losses were 10 percent higher than the reported figure of 37 percent in Haryana (Shah et al., 2004).

It is suggested that the straightforward neoclassical solution for introducing proper measurement, reducing theft, and promoting sustainable use is metering and tariff hikes. This is expected to send the appropriate price signals and encourage better management and efficient use (Dubash 2007). There is evidence that farmers use water more efficiently, increase gross water productivity and secure higher returns per unit of water used with higher tariffs. Introducing marginal cost for electricity motivates farmers to use water more efficiently through careful selection of low-water-intensive crops and livestock composition that gives higher returns from every unit of water (Kumar et al., 2011). Metered tariffs based on the cost of supply are credited with providing the right economic signals and enabling farmers to use as much electricity as necessary, making it possible to charge lifeline rates and giving the farmer benefit of lower prices during the off-peak period (Bhatia 2007).

However, it is argued that stretching metered tariffs beyond a certain point can reduce the effectiveness of the tool in conserving groundwater. Kishore and Verma (2003) did not find any significant difference in the behavior of pump owners with metered connections and those with flat rate connections. Further, there is evidence that strict rationing and metered tariffs hurt marginal water buyers and small farmers (Sidhu et al., 2020). Uttar Pradesh saw farmers replace their electric motors with diesel engines when metered tariffs were hiked in 1975. It is argued that power tariffs may be an ineffective instrument for regulating groundwater withdrawal due to a kink in the power demand curve under the current power tariff structure and power supply conditions (Saleth 1997).

Figure 4:1 Nature and shape of power demand curve



It is suggested that the power demand curve is not convex, but has a kink as depicted in the figure. Within certain range of power tariff, power consumption (hence groundwater withdrawal) is insensitive to variations in power tariff. The kink is due to two factors, firstly, farmers operate their pump up to the limit of the number of hours supplied by the utility and secondly, given that the margin between the energy cost and the net value of output per unit of power is high, farmers are expected to use electricity up till the additional output is appropriated as electricity charge. Consequently, with the actual power demand curve being ACD, any increase in tariff below the level of K in the figure will not induce farmers to reduce power consumption and hence, groundwater withdrawal.

Source: Saleth, 1997

Notwithstanding the divergent views on the merits of metering, the withdrawal of subsidies is considered politically infeasible in most critical groundwater states (Shah et al., 2012). The implementation of metering has proved elusive in states with the highest electricity subsidies. Ten Indian states accounting for 97 percent of total electricity consumption had only 27 percent of metered consumption in 2012-13 (Prayas 2018). Attempts at metering tube wells have been unsuccessful because of strong opposition from farmers' unions, this has been witnessed repeatedly in Punjab, (Birner et al 2011), and in Karnataka in 2003 when farmers burnt electric meters to express displeasure with the metering scheme (Mukherji and Das, 2014). Another drawback of metering is the high transaction cost. The cost of metering rural power supply in Uttar Pradesh and Maharashtra was estimated to be 26 percent and 16 percent of the revenues of the utility from the farm sector (Shah et al., 2004).

Subsidies are, therefore, likely to remain an important component of policy over the medium term. The relevant policy question is how to keep the subsidies as low as practically possible and adopt a more effective way of achieving sustainable resource use. Reducing stress on groundwater resources and public budgets is necessary as the economic and environmental costs imposed by free electricity far outweigh the societal benefits. Reforming the subsidy regime may be an economic process, but it invariably requires public acceptance and political will. Given that subsidies are embedded within the framework of the development of the rural economy in Punjab, the most important consideration for reducing subsidies is public opinion. Standard-menu reforms have often been too ideological in their conception, too rigid in their execution, and too narrowly focused on finance to deal successfully with changing investment conditions, the political complexities of reform implementation, and the combined economic and public benefit functions that an electricity system must serve. Better reform begins with a locally-specific framing of problems and targeting of solutions, not the idealized image of a perfect market (Williams and Ghanadan, 2006). A good deal of research has shown that behavioral factors influence the outcome of financial incentives and disincentives in that they can either complement or constrain the effects of financial incentives. Behavioral interventions have been recognized to play an important role in gaining public support for subsidy reform (OECD 2012).

4.3: Literature review

4.3.1: Incentivizing Behavioral Change for Resource-use Efficiency

Studies have found financial incentives to be effective in promoting environmentally significant decisions and behaviors, such as recycling (Bor et al., 2004; Timlett and Williams 2008); purchasing energy-efficient appliances (De et al., 2014; Stern 1999), and reducing energy consumption (Bertoldi et al., 2013; Ito et al., 2018). Interventions such as modifying market prices (through taxes or subsidies), offering conditional or unconditional financial incentives, and deploying non-monetary behavioral interventions or 'nudges' are found to change energy-use behavior (Sudarshan, 2017). Different incentive and pricing strategies are deployed to promote energy-saving behavior. 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). Similarly, rising block tariffs vary according to consumption levels (Sun and Lin 2013). Progressive tariffs penalize high consumption of electricity and electricity-saving feed-in-tariffs provide incentives to reduce the consumption of electricity (Prasanna et al., 2018). Demand response programs award participation payments usually as a bill credit or discount rate for consumers' participation in the programs (Albadi and El-Saadany, 2007).

Rewards are likely to be preferred over penalties by consumers. There is evidence that consumers prefer tariffs that reward decreases in electricity consumption, rather than tariffs that penalize increases in consumption. Tariffs combining rewards and penalties achieve substantial potential market acceptance (Mahmoodi et al., 2021). Consumer acceptance of tariffs with a penalizing component could be enhanced significantly when simultaneously offering a reward for decreases in consumption. These findings indicate that combinational reward-penalty tariffs are the most promising strategy to enhance consumer acceptance of penalizing components embedded in electricity tariffs (Mahmoodi et al., 2018). Useful lessons can be drawn from international experience about the ability to design tariff structures that are cost reflective, protect low-income consumers, differentiate tariff levels according to consumption levels and set the incentive framework right in the electricity sector (Clements et al., 2013).

In recent years, behavioral interventions also referred to as nudges, have been recognized as powerful tools in shaping people's behavior in a variety of domains. Behavioral approaches offer an exhaustive toolbox of strategies to help consumers overcome loss aversion and opt for incentive-based electricity tariffs, particularly those that apply financial penalties. Loss aversion reducing strategies could include framing to emphasize environmental and personal gains from subscribing to incentive-based tariffs, pre-selected tariffs kept as default options, etc. to nudge consumers toward incentive-based tariffs. Loss framed marketing messages which emphasize consumers potentially forfeited future savings by not subscribing to incentive-based electricity tariffs leverage loss aversion principles and promote acceptance of such tariffs (Mahmoodi et al., 2021). Both nudges and conditional incentives have grown increasingly popular in electricity demand management (Sudarshan 2017). However, consumer acceptance of incentive-based tariffs has not been examined in the context of agriculture in a developing country.

4.3.2: Discrete choice experiments

4.3.2.a: Studies in the Indian power sector

Some research has been conducted using the choice experiment methodology to examine willingness to pay for electricity in India. Bose and Shukla (2001) estimated the willingness to pay for electricity supplied from the grid. Willingness to pay was determined based on the cost of generating electricity through alternative means during power outages for agricultural, residential, and industrial consumers in Gujarat. The study found that it would be feasible for agricultural consumers to pay a moderate price for electricity. Many farmers reported that they would like to have the hours of supply extended, and some were willing to pay more for it. For an average farm using about 1550 kWh of electricity a month for irrigation, it was estimated that an increase in the price of electricity by Rs. 1/kWh ($0.013) would represent an increase in the monthly expenditure on agricultural inputs of about 20 percent. The authors suggested that if agriculture must continue to be subsidized, then this should be done with direct subsidies rather than through lower electricity prices.

In the context of free electricity for agriculture and extremely low levels of groundwater levels in Tamil Nadu, Gajanan et al., (2014) examined whether farmers would be tempted to pay for a hypothetical package of reliable electricity, to reduce the opportunity cost of voltage fluctuations, repair, and burnout. The survey revealed that marginal and small farmers place a positive value on reliable power. Medium and small farmers who are the biggest beneficiaries of free electricity were not willing to pay for the hypothetical package. Assuming that electricity subsidies to agriculture must continue for political reasons, Dossani and Ranganathan, (2004) advocate discriminatory pricing i.e., charging a higher price for greater usage of power. The question of how much price could be raised was examined in the backdrop of political acceptability as raising prices was likely to reduce affordability by the marginal farmer and cause potential political problems. A combination of doing away with rostering and improving the supply parameters was recommended as a way to reduce subsidies substantially. Further, a greater discriminatory pricing regime than the current regime was forecasted to increase revenue by 20 percent.

The contingent valuation methodology used by Gunatilake et al., (2012) found that the willingness to pay of rural consumers for increased hours of electricity supply, better customer service, and accuracy of billing was high enough to justify investment in Madhya Pradesh. Good quality uninterrupted supply was considered a top development priority by rural households. 90 percent of the households would continue to use electricity as long as the monthly bill was lower than Rs. 100 ($1.28) in 2012. Approximately 75 percent of the high-income groups were willing to pay Rs. 200 ($2.56) per month while only 45 percent of poor households would accept improved service with this bill amount. They found that 90 percent coverage of low income, below the poverty line, and scheduled caste and scheduled tribe households could be achieved with very low, or no subsidies. Block tariffs had the potential to induce energy conservation as they led to a drastic reduction in uptake rates for higher-income groups.

Kennedy et al., (2019) estimated the willingness to pay of Rs. 399 ($6.18) of an average non-electrified rural household. Quality of power and willingness to pay was found to have a positive relationship in rural India. A one-hour increase in availability was estimated to increase willingness to pay by about Rs. 52 ($ 0.81) and one hour increase in nighttime hours would increase willingness to pay by about Rs. 136 ($2.12). The study confirmed the importance of high-quality service for the willingness to pay in respect of non-electrified rural households in India. Improving the quality of service was recommended to increase households' willingness to pay. A policy implication of the results was that improving the quality of service would increase rural households' willingness to pay for electricity and the revenues in turn would cover the real cost of generating, transmitting, and distributing electricity.

Blankenship et al., (2019) found that willingness to pay for service improvements was generally low, although there were variations across rural and urban households in Uttar Pradesh. Willingness to pay ranged from 0-200 rupees ($0-2.56) with a mean of 36.7 and a standard deviation of 46.9. They found that respondents' support for service improvement and their willingness to pay was in large part driven by their levels of social trust. Generalized trust was a robust predictor of willingness to pay. There was no evidence of a sense of entitlement as a predictor of low willingness to pay. Delays in service improvements and lack of community support for pricing reform were found to reduce willingness to pay.

Sagebiel and Rommel (2014) found a low willingness to pay value in respect of Hyderabad's domestic consumers. While 90 percent of the households were unwilling to pay more for reliability, those with higher income, smaller households, and higher electricity expenditure, showed a preference for better quality of supply.

Gill et al., 2017 undertook a comprehensive literature review on the willingness to pay studies for electricity services in India. The average estimated rural domestic consumer's willingness to pay for grid electricity supporting all facilities was Rs. 290 per month ($ 3.71). One of the findings was that willingness to pay could not be the sole factor for bridging the gap between the average cost of supply and the realized revenues in Uttar Pradesh. It was suggested that other simultaneous measures such as improvements in operational efficiency and reduction in Aggregate Technical & Commercial losses, conversion of unmetered connections to metered ones, and an increase in the hours of supply would be required to reduce the gap. Discussions with electricity regulators showed that consumers' willingness to pay was not considered whilst setting tariffs, pricing was done on a 'cost-to-serve' basis, using data provided by electricity distribution companies and/or on studies undertaken by regulators. They suggested that cost-reflective tariffs could be introduced by creating awareness of the true cost of electricity among consumers, pursuing independent pricing policies, and targeting subsidies.

4.3.2.b: Other Studies on Willingness to Pay

Choice experiments conducted in other countries are reviewed in this sub-section. Figure 4.15 in the Appendix carries a list of discrete choice experiment studies. Richter and Pollitt (2018) analyzed customer valuations for smart electricity service attributes and contracts in a stated preference experiment in the UK in 2015. The six choice attributes included monitoring of energy usage, control of electricity usage, technical support with set-up and usage, data privacy and security services, expected electricity savings, and fee for service bundle. The results highlighted significant heterogeneity in the valuation of the attributes. Customers expected significant compensation for monitoring and control and for sharing usage and personally identifying data. Some consumers asked for very high compensation to share their data, of more than £10 per month, while some perceived the data services as valuable and were willing to pay for these services. The average compensation required was £2.20 per month. A fixed monthly compensation of £3 per month was found to be accepted by more than 75 percent of the customers. Customers were willing to pay for technical support and premium support. They showed a willingness to pay about £0.33 per expected pound saving if the ratio of fee to expected saving was relatively low. Most were willing to pay a third of what they expected to save. This study formed a useful basis for designing and conducting the experiment in this study.

Abdullah and Mariel (2010) estimated willingness to pay for improved electricity service in Kisumu Kenya. The attributes included duration and frequency of outages, type of distribution provider, and costs of electricity consumption. The mean willingness to pay for the attribute of frequency of outage was KSh 51.79 ($0.44) for the base scenario. The median willingness to pay for the second attribute of the duration of the outage was KSh 61.87 ($0.53). Cost, frequency, and duration of outages were significant factors as respondents preferred fewer outages with shorter duration. Cost interactions gave negative coefficients for older people, people resident in the area for a longer time, and the unemployed. Positive and significant coefficients were revealed for bank account holders, larger households, and those engaged in farming. Drawing upon this approach, the current study explains the variation in the preferences with regard to the socio-economic characteristics of respondents.

Carlsson and Martinsson (2008) investigated preferences for power cuts between summer and winter time and between weekdays and weekends of Swedish consumers. A higher willingness to pay was observed for avoiding power cut during weekends in winter. There were increasing values with the duration of the power cut. The marginal willingness to pay for avoiding a 4-hour outage during weekdays was SEK 9.64 ($0.96) and 4-hour outage during the weekend was SEK 31.73 ($3.15). The marginal willingness to pay for avoiding 24-hour outages during weekends in winter was higher at SEK 134.96 ($13.39) as compared to SEK 103.16 ($10.23) during weekdays. During weekends, more members of the households were at home, compared to weekdays, and the marginal WTP increased with the duration of the outage. Respondents living in big cities and detached or terraced houses were found to have a lower willingness to pay to reduce power cuts.

Amador et al., (2013) conducted a choice experiment with attributes of reliability of service, the share of renewable energy, and availability of energy audit services in the Canary Islands. They found significant willingness to pay values for the reduction of power cuts, especially from persons with experience of power cuts. An individual with an average household income and assigning an average rating to the importance of last outages was willing to pay $ 2.11 more per month (4.2 percent of the monthly bill) to reduce the number of unscheduled outages by one unit. The willingness to pay for renewable energies was higher for graduates ($0.49) than for non-graduates ($0.33) at the middle level of household income.

Ozbafli and Jenkins (2016) investigated willingness to pay for reliable electricity services with five electricity service attributes - frequency of outages, duration of outages, time of outages, prior notification, and percentage change in monthly electricity bills in North Cyprus. The willingness to pay per hour unserved was YTL 0.28 ($0.24) for summer and YTL 1.08 ($0.92) for winter. Compensating variation estimate for the zero-outage scenario was YTL 6.65 ($3.02) per month for summer and YTL 25.83 ($ 11.74) per month for winter. The annualized economic benefit of YTL 42.7 million (419.4 million) was sufficient to justify the additional investment of 268 MW in generation capacity to eliminate the service reliability problem.

Siyaranamual et al., (2020) used a discrete choice experiment and applied two estimation methods, mixed logit, and latent class logit to show significant heterogeneity in preferences for electricity service attributes in Bandung, Indonesia. It was estimated that consumers were willing to pay to reduce the outage duration to 2 hours/year, with WTP ranging from IDR5,000 ($1.18) to IDR61,500 ($14.49) per month, depending on the size of the installed capacity. With the increase in rural electrification ratio to 100%, it ranged from IDR17,600 ($4.15) to IDR215,000 ($50.64) per month.

Huh et al., (2015) applied the contingent valuation method to elicit the willingness of Korean households to pay more for their energy bills to support the enforcement of three policies – renewable portfolio standard (RPS), renewable fuel standard (RFS), and renewable heat obligation (RHO) in the transportation and heating sectors in 2015 and 2016 respectively. The monthly mean WTP for RPS, RFS, and RHO was estimated as KRW 3287.5 ($2.56), 4432.9 ($3.45), and 3971.1 ($3.09). The five non-monetary attributes were residential electricity service, smart meter installation, number of blackouts (yearly), duration of each blackout, and social contribution of the electric power company.

Willingness to pay for water service has been estimated for countries in Latin America and Asia (Casey et al., 2006, Fujita et al., 2005). There are indications of willingness to pay for reliable irrigation water in the south Asian Indus basin, contrary to the political narrative shared by countries in the region. The mean marginal willingness to pay for improved surface water reliability in the Punjab province of Pakistan was much higher than the current average rates of $0.41-0.96 per acre, and farmers with the best ability to pay in the head reaches were willing to contribute more for water supply they could rely upon (Bell et al., 2014). Several previous studies have also examined the value of groundwater protection in groundwater-stressed areas. A contingent valuation method was applied to estimate median willingness to pay of $40 per household for a hypothetical groundwater protection plan in Dover in England (Shultz and Lindsay, 1990). Residents in the Mekong delta area in southern Vietnam were willing to pay approximately $6.74 per household per year for a groundwater protection plan (Vo and Huynh, 2017). Marginal willingness to pay for the protective value of groundwater equaled $ 1.97 per year per household in the Qazvin plain in Iran (Mortazavi et al., 2019). The average willingness to pay of $0.08/m3 for an improvement in the irrigation supply in Tunisia was 63 percent higher than the current charged water price (Abdelhafidh et al., 2022). Burton et al., (2020) used a discrete choice experiment to understand the preferences of farmers for water charging and irrigation administration in India and Pakistan. Farmers complying with payment behavior preferred local retention of revenues in India, while this did not extend uniformly across Pakistan.

A review of the relevant literature indicates that there are a large number of choice experiments conducted on examining consumers' preferences for improved electricity attributes, green electricity, and groundwater protection. Limited research has been undertaken to investigate preferences for incentivizing energy-saving behavior among farmers in developing countries. This study is the first of its kind, as the willingness to opt for metered consumption and accept incentives for saving electricity in agriculture has not been adequately researched in Punjab.

4.4: Discrete choice experiment approach

4.4.1: Context of valuation of the proposed objectives and attributes

Given concerns of rapid groundwater depletion in Punjab, many experts advocate the ‘getting the price right’ approach to improve irrigation efficiency and efficiency of utilities. Punjab’s rural economy is over-dependent on groundwater and subsidized agricultural electricity, hence the abrupt withdrawal of subsidies is not feasible. An alternative approach is to transfer the subsidy amount directly to the farmers' bank accounts and let them pay the market price for the inputs they use (Johl et al., 2014). The actual subsidy could be directed to the farmer as a tradeable coupon or stamp (Morris 2001). However, such a program would require large upfront cash transfers and burden the existing administrative system, which is infeasible in India (Mitra et al., 2021).

Instead of cash transfers, a voluntary approach piloted in Kukarwad, Gujarat, invited well owners to install meters on their pumps and receive compensation per unit reduction of electricity use below a benchmark 'entitlement' (Fishman et al., 2016). Implementation of electricity quota can exercise an indirect control on water pumping. It is considered relatively costless and fairness among farmers can be ensured (Zekri 2008). Farmers oppose metering as they perceive that this would bring an end to the policy of free electricity. The voluntary nature of the approach and lack of any imposition on farmers' water usage was considered more acceptable to well owners than one based on regulation or direct pricing (Fishman et al., 2016). This compensation approach is similar to the concept of energy conservation rebate (Wolak 2010) and payment for ecosystem services which compensates individuals or communities for undertaking actions that increase the provision of ecosystem services. Offering constant marginal benefits such as per unit tax or incentive can be used to predictably reach a given environmental target (Jack 2007).

Fishman et al., (2016) emphasized the need to test the voluntary approach of 'electricity entitlement' in other geographies to better understand its effectiveness in modifying pumping behavior. A scheme titled 'Paani Bachao Paise Kamao' (Save Water Earn Money) is being tested on a pilot basis by the Punjab government with the support of the World Bank and J-PAL. Under this scheme, meters are installed on the pumps of enrollees. An average monthly electricity quota based on motor capacity is fixed for each feeder according to the season. The formula for determining the quota is the previous year's electricity usage divided by the total tube well load on the feeder. The average is worked out on a seasonal basis, considering two major cropping seasons i.e., paddy season (from June to September) and non-paddy season (from October to May). The quota is higher for the paddy season and lower for the non-paddy season. Farmers are paid Rs. 4/kWh for using less electricity than their quota (PSPCL Commercial circular 2022).

To further advance research about the entitlement approach, this chapter collects evidence about farmers' stated preferences for adopting an annual limit of free electricity and offer of an incentive for achieving energy savings within the annual limit in Punjab. The attribute of saving incentive was included in this study for its impact on incentivizing reduction in electricity consumption and bringing significant welfare-enhancing benefits for poor farmers. The difference in this chapter from previous pilot studies is the inclusion of a disincentive for use beyond the electricity quota. The electricity quota can be made effective by charging a dissuasive price for electricity use beyond the allowed limit (Zekri 2008). Apart from the direct impact on reduced use of energy, it is expected to aid in adopting environmentally conscious behavior.

Metering of agricultural connections is emphasized for improving the estimation of agriculture consumption, enhancing accountability, and enabling rational tariff fixation (Honnihal 2004). Metering and charging pro rata for power used are regarded as the best options to manage groundwater and energy economy (Kumar et al., 2011). Despite clear government directives for 100 percent metering, progress on the ground is marginal. Resistance to the metering of irrigation pumps is formidable. An alternative approach of offering credits or bonus reward for installing electric meters is prevalent in some geographies (Xiqin et al., 2022, Ovo energy, 2020). Some demand response programs offer compensation such as fixed monthly payments for enrolling in programs (Gagne et al., 2018). Transparent and adequate financial rewards have helped to overcome customers' inertia toward dynamic pricing (Faruqui et al., 2010). Drawing insights from these best practices, reward payment for meter installation was included in this study.

This study applies a stated preference binary choice experiment to examine farmers' stated preferences for the attributes of the fixed annual limit of free electricity as a substitute for unmetered and free electricity supply; reward for installing meters to measure free electricity limit; the incentive to encourage savings and offset any losses incurred due to imposition of a restrictive quota; and electricity charge to dissuade use beyond the allowed limit. The selected attributes are expected to instill some degree of discipline in farmers' pumping behavior, save the government's expenditure on subsidies and generate some revenue for the distribution utility. The attributes and levels selected for inclusion in the stated preference choice experiment are detailed below.

4.4.2: Description of Attributes and Levels

4.4.2.a: Annual limit of free electricity

The current study applies an attribute of electricity entitlement for investigating preferences for metered consumption among Punjab farmers. The attribute of electricity entitlement has two levels, 1500 kWh and 1550 kWh of free electricity units offered on a per acre basis. For arriving at these two levels, baseline electricity entitlement was determined to reflect the existing usage of electricity by Punjab farmers. Estimating this minimum entitlement based on actual consumption was difficult as comprehensive data on past usage is not available, except for data from some sample smart meters installed by Punjab State Power Corporation Limited. The author relied upon studies, and inputs of farm use given by farmers for the determination of the annual limit of free electricity. Electricity requirement was calculated for an average farmer growing two crops – wheat and rice in a year. The prevailing seasonal supply schedule was ascertained from the Punjab State Power Corporation Limited and cross-verified with the farmers to arrive at average hours of power usage. The average connected load was multiplied by the estimated number of hours of power usage to determine the entitlement of 1500 kWh per acre and 1550 kWh per acre.

The consumption of electricity for irrigation varies due to changes in season, crops grown, and water table level in different parts of the state. While determining electricity entitlements, an important consideration was to ensure that the annual limit of free electricity was not underestimated considering the regional variations and to incentivize genuine efforts to reduce electricity use.

The reward for meter installation

A prerequisite to the provision of an annual limit of free electricity is the metering of agriculture connections. The offer of a fixed payment linked to the annual farm output could potentially increase the participation of farmers in meter installation. Developing an understanding of the effect of reward on motivating meter installation can serve as the starting point for reforming the prevailing regime of unmetered consumption in Punjab. The attribute of the annual limit of free electricity on a per acre basis was combined with a reward payment of Rs. 20 ($0.25) per quintal on the annual farm output produced on a per acre basis. Assuming annual farm output of 48 quintals per acre, the reward scheme would generate an average extra income of Rs. 960 ($12.05) per acre @ Rs. 20/quintal. This amount was carefully calibrated to generate 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.

The policy change alternative offered farmers two levels of entitlement of free electricity combined with a fixed reward payment for the meter installation in the choice experiment. Farmers were informed that in case they did not want to opt for the policy change alternative, they could continue to receive unlimited and unmetered free electricity to pursue their present pattern of electricity consumption without any reward for saving or charge on consumption.

Incentive on saving electricity within the annual limit

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 who receive rewards tend to save more than those who do not (Abrahamse et al., 2005). Drawing upon the rich literature emphasizing the importance of incentives in promoting energy savings and exploring the effect of monetary incentives on inducing energy-saving behavior among farmers in Punjab, cash incentive for reducing electricity use within the annual limit of free electricity units was included in the choice experiment. It has two levels - Rs. 2($0.02)/kWh and Rs. 3($0.03)/kWh paid for each unit of electricity saved within the allowed annual energy limit.

4.4.2.b: Electricity Price

In a choice model, price is usually included as one of the attributes to arrive at willingness to pay/willingness to accept 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 is Rs. 5.66 per kWh in Punjab. Such a high per unit rate may not be affordable to all farmers. Therefore, two levels of a reasonable electricity tariff of Rs. 1($0.01)/kWh and Rs. 2($0.02)/kWh were included as the price attribute in this choice experiment.

4.4.3: Experimental design

The scope of the choice experiment was governed by practical considerations. It was anticipated that increasing the cognitive burden of the choice task could reduce the response rate for the questionnaire. Large number of choices or attribute levels may lead to respondent fatigue bias or loss of interest in the task. It was decided to include no more than eight scenarios in the experiment. There were two attributes, one with three levels and the other attribute with five levels. A full factorial design across the two attributes would require 15 scenarios, which would be lengthy and infeasible. Therefore, a fractional factorial design was generated from the full factorial 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. A pilot study was undertaken with farmers in 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. Attributes and levels are presented in figure 4.2 and example of a choice set is shown in figure 4.3.

Figure 4:2 Attributes and Levels

Attributes	Levels
1. Annual energy limit of free electricity and reward for conserving electricity	No energy 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

For each choice scenario, respondents were asked to indicate whether they were likely to prefer the hypothetical metered consumption alternative or not. 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 adopt the metered consumption hypothetical alternative or not?") was adopted as it better reflects the nature of the problem faced in agricultural consumption of electricity in Punjab. The purpose of the study was explained to the farmers selected randomly. A description of each of the attributes and levels was provided at the beginning of the questionnaire. Respondent identity was kept confidential during analysis. Each respondent was presented with eight choice sets and prompted to indicate the likelihood of taking up or not. It was checked whether the respondent always chose the alternative with the highest level of the attribute or in other words, are there dominant preferences. In general, there were extremely few dominant preferences.

Figure 4:3 Example Choice Set

Attribute	**Intervention versus status quo**
Annual free electricity limit and saving incentive	1550 kWh/acre, Rs. 20/q reward and Rs. 2/kWh incentive for saving electricity Free 1550 kwh per acre + ₹ 2/kwh Incentive Meter
Price of electricity	Rs. 1/kWh charge for consumption Rs. 1/KWh charge on overuse
Would you take up this intervention? Please tick	*Yes* ☐ *No* ☐

4.4.4: 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

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (4.1)$$

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

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

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

$$P_{ni} = P_r[\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}] \qquad (4.2)$$

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

$$Adoption_{in} = \beta_0 + \beta_1\, xLimit1500_{2_{in}} + \beta_2\, x\, Limit1500_{3_{in}} + \beta_3\, x\, Limit1550_{2_{in}} + \beta_4\, x\, Limit1550_{3_{in}} + \beta_5\, x\, Electriccharge_{1_{in}} + \varepsilon_{in} \tag{4.3}$$

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. For the attribute of annual limit and saving incentive, 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.

4.4.5: 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)

$$\Delta V = \alpha_1 x Limit + \alpha_2 x Price + \theta + \varepsilon \qquad (4.4)$$

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/accept for levels of individual attributes (Ryan and Hughes, 1997, Ryan et al., 2007).

4.5: Empirical results

The empirical analysis in this chapter is based on survey of 859 farmers conducted across twenty districts of Punjab. Every respondent was presented with eight binary choices of taking up the annual limit of free electricity with cash incentive or not. As each respondent had to make eight choices, this yielded 6872 observations. The overall goodness of fit indicated by the pseudo-R-squared value was 0.24.

i) Logit and probit results: Results presented in figure 4.4 report the probability of take up of annual limit of free electricity with cash incentive for saving electricity. Regarding the significance of the estimated coefficients, the random effects probit and conditional logit models are well specified. Dummy variables were incorporated to account for non-linearities and were helpful in separately estimating the effect of each level. Limit 1500_3 specifies the annual limit of 1500 kWh/acre and cash incentive of Rs. 3/kWh; Limit 1550_2 specifies the annual limit of 1550 kWh/acre and cash incentive of Rs. 2/kWh and Limit 1550_3 specifies the annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh. Annual limit of free electricity was offered with reward of Rs. 20/quintal on annual farm output. Price attribute is the price of electricity at Rs. 1/kWh and Rs. 2/kWh charged on consumption beyond annual limit.

The results of the random effects probit and conditional logit models show that the coefficients for all attribute levels are statistically significant. The direction of farmers' preferences for attributes is as anticipated. In other words, the preference of average farmers increases in proportion to the annual limit of free electricity limit, and cash incentive for saving electricity. The results demonstrate clear preference for the higher annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh followed by 1550 kWh/acre limit and incentive of Rs. 2/kWh. Farmers also prefer the annual limit of 1500 kWh/acre with incentive of Rs. 3/kWh, though the valuation was lower than for the higher annual limit. *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, then the farmers are more likely to choose the status quo.

Figure 4:4 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

ii). Odds Ratio: The coefficients in a logistic regression model correspond to the change in the log odds and these coefficients can be exponentiated to give Odds ratio. An Odds ratio is the odds of the event in one group (exposed to the policy alternative) divided by the odds in another group not exposed to the alternative.

Figure 4:5 Odds Ratio

Attribute	Coefficient	Std. Error
Limit 1500_3	4.3361***	0.3646
Limit 1550_2	12.1985***	1.0760
Limit 1550_3	14.2159***	1.2715
Price of electricity	0.55902***	.03104
Log likelihood	*-2482*	
Pseudo R^2	*0.24*	
N	*6872*	

****p < 0.05*

The Odds ratio shows strong association of the attribute of higher annual limit of free electricity and cash incentive with choice preferences as odds ratio for the annual limit of 1550 kWh/acre with Rs. 3/kWh incentive for cash electricity is 14 times higher, and Odds ratio for 1550 kWh/acre free units and incentive of Rs. 2/kWh is 12 times higher.

iii) Willingness to pay/willingness to accept: The estimated coefficients are supported by willingness to pay/willingness to accept (WTP/WTA) values. The WTP/WTA is given by the following formula (Ryan et al., 2012):

$$Willingness\ to\ pay = \frac{\beta_{Limit}}{\beta_{ElectRte}} \tag{4.5}$$

where Limit refers to annual limit of free electricity unit and ElecRte refers to the rate of electricity. Willingness to pay values are presented in the figure 4.6 below. Farmers are willing to pay more for the higher annual limit of 1550 kWh/acre and Rs. 3/kWh cash incentive than for a lower annual limit of free electricity and lower cash incentive for saving electricity. They are willing to pay least for the annual limit of 1500 kWh/acre and cash incentive of Rs. 3/kWh for saving electricity. The similarity of results in the logit and probit models suggests a high level of convergent validity between the two models.

Figure 4:6 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*

The figure 4.7 shows the WTP/WTA estimates and 95% confidence intervals for the three attribute levels of annual energy limit and cash incentive.

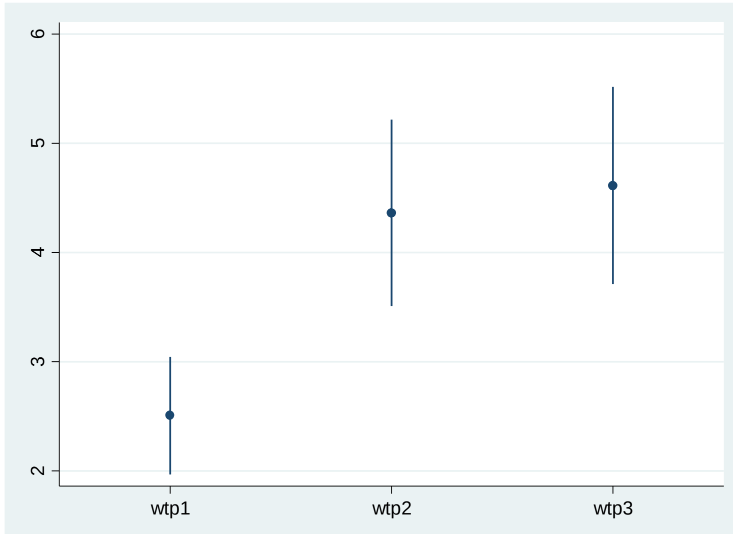


Figure 4:7 Willingness to pay estimates and 95% confidence intervals

v) Marginal effects: Parameter estimates from discrete choice model can be transformed to yield estimates of marginal effects – that is change in the predicted probability associated with changes in the explanatory variables. The marginal effects are presented in figure 4.8. Annual limit of 1550 kWh/acre and Rs. 3/kWh cash incentive increases the probability of acceptance by 50 percent points. The marginal effect for annual limit of 1550 kWh/acre and a smaller cash incentive of Rs. 2/kWh is 47 percent points and considerably lower at 27 percent points for the lower annual limit of free electricity of 1500 kWh/acre and cash incentive of Rs. 3/kWh.

Figure 4:8 Marginal effects

Attribute	dy/dx	Std. Err.	dy/dx	Std. Err.
	Random effects probit		Conditional logit	
Limit1500_3	0.2742***	0.0143	0.2545***	0.0108
Limit1550_2	0.4773***	0.0122	0.4339***	0.01103
Limit1550_3	0.5046***	0.0119	0.4604***	0.0114

****$p < 0.05$*

vi) 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. The probability of uptake for the different attribute levels has been estimated. The uptake probability was predicted to be 69 percent for the annual limit of 1500 kWh/acre and Rs. 3/kWh cash incentive, as shown in figure 4.9. However, the uptake probability increased to 82 percent with increase in annual limit to 1550 kWh/acre and cash incentive of Rs. 2/kWh, and 84 percent with annual limit of 1550 kWh/acre and cash incentive of Rs. 3/kWh respectively.

Figure 4:9 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 is simulated in figure 4.10 below. The results demonstrate that probability increases by 30.6 percent for annual 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. This shows that increasing the annual energy limit has a relatively greater impact on promoting acceptance than increase in cash incentive.

Figure 4:10 Change in probability

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

****p* < 0.05*

iii). Comparison of coefficients between the regions: Doaba region of Punjab shows the highest preference for accepting the annual limit of free electricity and cash incentive. The region also demonstrates the smallest negative preferences for paying electricity price on consumption in excess of the annual limit of free units as shown in figure 4.11.

Figure 4:11 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***

****$p < 0.05$*

iv) Results of Interaction terms with socio-economic and demographic characteristics

The logit model assumes that preferences are homogenous across individuals. However, there can be significant heterogeneity in valuations. A solution to this problem is to interact specific individual variables, such as age, education, asset ownership with various choice attributes. Interaction terms between attributes and respondent characteristics can provide insights into what drives the preference heterogeneity. Segmentation analysis has been conducted to determine the effect of socio-demographic characteristics on farmers' preferences for the different attributes.

Education has a positive impact on the preference for moving away from status quo. Matriculate farmers are more likely to significantly prefer annual limit of 1550 kWh/acre of free electricity and cash incentive of Rs. 2/kWh to save electricity. Farmers with education above graduation are likely to significantly reject payment 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 select the status quo alternative with lower annual limits, and the likelihood of choosing the status quo is expected to decrease for small, medium, and large farmers, although these results are not significant. Figure 4.14 in the Appendix shows results of the interaction terms of the attribute levels with age, education, connected load, tube well ownership and land size.

4.6: Discussion

The results of this discrete choice experiment demonstrate that the coefficients for the annual limit of free electricity and cash incentive are significant and result in higher valuations for the higher annual limit and cash incentive. About 70 percent of the farmers are likely to accept 1500 kWh per acre and a cash incentive of Rs. 3/kWh. The acceptance rate increases to 82 percent for the higher annual limit of 1550 kWh/acre and Rs. 3/kWh cash incentive. These acceptance rates are reported by the farmers if they were charged Rs 1/kWh for excess consumption. It was found that the farmers care about the negative effect of paying a price for electricity consumption beyond the annual limit of free electricity. The acceptance rate for 1500 kWh/acre and cash incentive of Rs. 3/kWh is 23 percent at the higher electricity charge of Rs. 2/kWh. About 50 percent of the farmers are likely to prefer 1550 kWh/acre and a cash incentive of Rs. 2/kWh if they are confronted with payment of electricity tariff of Rs. 2/kWh for excess consumption. However, 84 percent of the farmers are willing to accept 1550 kWh/acre and a cash incentive of Rs. 3/kWh, even if there was a charge of Rs. 2/kWh on consumption beyond the annual limit. The results broadly concur with previous findings of preferences for incentives to motivate energy savings and the positive effect of introducing electricity entitlements (Fishman et al., 2016).

There is significant heterogeneity in the valuations for most of the attributes. Results illustrate that a mixture of an annual limit of free electricity and payment of cash incentives to the farmer could promote the acceptance of metered consumption. However, the higher annual limit of free electricity of 1550 kWh/acre units constitutes a more important attribute than the cash incentive. A necessary condition for acceptance is forming a rational link of the annual limit to the level of irrigation service sufficient to meet farmers’ minimum irrigation needs. It is found that pricing electricity (even a nominal variable rate) could be made acceptable by offering a higher annual free electricity limit and cash incentive. From a financial perspective, the finding of preference for a cash incentive to motivate reduced consumption is favorable as the incentive could be financed from subsidy savings.

From an economic point of view, marginal pricing of water and electricity can achieve efficient use of groundwater. In practice, however, socially efficient pricing may be impractical in developing countries as previously discussed in this chapter. An indirect method of minimizing over-extraction of groundwater is fixing quantitative ceilings on per hectare use of electricity for groundwater extraction. The findings prove that exposing the farmer to annual limits and awarding economic incentives for unused units of power less than the limit can potentially translate into reduced demand. One potential explanation is that introducing cash incentives for saving electricity increases the marginal returns of not mining water and raises the opportunity cost of pumping groundwater. Raising the opportunity cost of electricity for pumping groundwater can function as de facto regulation of groundwater use and reduce the common pool externality.

It is argued that the promotion of water-saving technologies may fail to realize their full potential without the introduction of incentives for the 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). This study provides firsthand insight into the potential of introducing annual energy limits and reward-penalty electricity tariffs for reducing electricity consumption in an Indian State where the supply of electricity to agriculture is free and unmetered.

The underlying model is that shifting the subsidy from electricity to incentive for reducing consumption can drive behavioral change to save water consciously. This information is very important in light of intensified concerns about a rapid deterioration in water table levels and increase in carbon emissions, and the urgent need to pursue sustainable resource use policies. To test the economic viability of such a strategy, the costs and benefits of this strategy need to be evaluated.

To perform the cost-benefit analysis, it is assumed that the current supply of free electricity is around 2090 kWh per acre. This figure is arrived at by averaging the highest and lowest electricity entitlement for a 10 HP and 25 HP electric pump allowed under the existing Pani Bachao Paise Kumao scheme. However, the energy entitlement may be higher due to varying levels of groundwater availability coupled with diminished water discharge, which makes farmers use heavy-duty motors in water-stressed areas. Regarding the conservative average entitlement of 2090 kWh/acre, it is likely that there would be a saving of 540 kWh per acre in case the annual limit of 1550 kWh per acre is imposed. This amounts to a saving of electricity subsidy of $38.37 per acre. After deducting the cost of reward for meter installation, the net saving would be $26.32 per acre for the government. Calculated for the entire state, this strategy could save about $267.86 million annually.

The saving of electricity subsidy, groundwater and carbon emissions is likely to be much higher when estimated based on the actual supply schedules notified by the utility, though there may be some variation due to local interruptions. Projections on the basis of actual supply (by averaging the supply for 10 HP capacity motor over land holding size of 5 acres and 25 HP capacity motor over 8 acres of land) estimate annual saving in electricity subsidy for the entire state of around $1236.5 by shifting to the annual limit of 1550 kWh/acre. The government could finance the cash incentive offered for reducing consumption out of the savings generated from reduced electricity subsidies.

Figure 4:12 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	ton	0.4428

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

The above figure establishes the economic rationale for switching to annual energy limits and incentive-based strategies for promoting energy and water savings. However, the provision of reliable and stable electricity within the allowed limit of free electricity would be essential for generating savings in electricity subsidies and groundwater. If there is uncertainty regarding supply, risk-averse farmers are likely to over-irrigate their fields whenever power is supplied to them. A study found that 74 percent of farmers in three main paddy growing districts of Punjab were willing to accept metered electric connections and to pay for good quality supply, though there was variation across regions. Typically, farmers defined supply quality as, "better voltage, fewer fluctuations, longer hours of supply, and daytime supply," since monitoring was difficult during night-time supply. Further, farmers were willing to pay for additional supply and metered consumption if additional costs were reflected in the Minimum Support Price (Gulati and Pahuja, 2012). Given farmers' tendency to over-pump water in the face of unpredictable and sporadic power availability, a strictly scheduled supply at preannounced hours is expected to discourage wasteful behavior (Sidhu et al., 2020). Tariff increases concomitant with improvements in the quality of service have resulted in durable tariff reform in other countries (Clements et al., 2013). Therefore, policymakers may consider implementing supply schedules to match with seasonal and regional demand for irrigation water (Shah et al 2004).

4.7: 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. Indirect measures to replace 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, introducing annual energy limits and incentive-based demand response programs needs farmers' willingness. This study assesses the willingness and interest of farmers to participate in an incentive scheme combined with a meter option based on a discrete choice experiment conducted with 859 farmers in Punjab in 2021-22. Farmers are willing to move away from unmetered consumption with inducements of cash incentives and an annual limit of free electricity sufficient to meet irrigation requirements.

The random effects probit and conditional logit models consider the preference heterogeneity for the valuation of energy limits, incentive schemes, and pricing of electricity. This study highlights the acceptance of both carrot and stick policies for motivating behavioral change. An annual limit of 1550 kWh/acre units of free electricity is accepted by 82 percent of the farmers. Farmers are likely to have higher acceptance of the annual energy limit supplemented by cash incentives to reduce consumption within the stipulated limit of free electricity. The combined incentive-penalty based tariff is effective in inducing greater participation. The results illustrate the acceptance of variable electricity rates on consumption beyond the annual free limit and that the acceptance of electricity prices could be increased by offering a higher annual limit of free electricity. The results show that a moderate rate of cash incentive and electricity price is acceptable to about 71 percent of the respondent farmers. Preference for incentives demonstrates the saving intention of farmers and that cash incentives can energize behavior towards saving electricity. A variable charge on electricity is likely to make farmers aware of the real cost of power and water and force them to economize on its use.

The econometric estimation also allowed the estimation of farmers' valuation and trade-offs for different levels of the annual limit of free electricity. It is found that farmers are willing to sacrifice Rs. 4.30($0.05)/kWh for 1550 kWh/acre limit of free electricity and a 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 inform the design of schemes to deliver free electricity to agriculture and 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 limits of free electricity and cash incentives to adopt energy-saving behavior. Educated farmers are more likely to value the annual limit associated with rewards for reducing consumption.

The significant heterogeneity in valuation for the attributes suggests that efficient implementation of metering requires customized schemes. From a public policy point of view, the findings suggest that government may have an interest in targeting free supply to small farmers and introducing metered consumption for relatively larger farmers. 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 savings in electricity subsidy could compensate for the additional costs incurred in rewarding energy-saving behavior. 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 the meter option.

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 meter option, which may not do away with subsidies, but can certainly complement efforts to contain electricity subsidies and groundwater extraction.

References

Abdelhafidh, H., Brahim, M. B., Bacha, A., & Fouzai, A. (2022). Farmers' willingness to pay for irrigation water: Empirical study of public irrigated area in a context of groundwater depletion. Emirates Journal of Food and Agriculture 34(1), 44-50.

Abdullah, S., & Mariel, P. (2010). Choice experiment study on the willingness to pay to improve electricity services. Energy policy, 38(8), 4570-4581.

Abdullah, S., & Jeanty, P. W. (2011), Willingness to pay for renewable energy: Evidence from a contingent valuation survey in Kenya, Renewable and Sustainable Energy Reviews, 15(6), 2974-2983.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology, 25(3), 273-291.

Akcura, E. (2011). Information effects in valuation of electricity and water service attributes using contingent valuation. EPRG Working Paper 1127.

Albadi, M. H., & El-Saadany, E. F. (2007, June). Demand response in electricity markets: An overview. In 2007 IEEE power engineering society general meeting (pp. 1-5).

Amador, F. J., González, R. M., & Ramos-Real, F. J. (2013), Supplier choice and WTP for electricity attributes in an emerging market: The role of perceived past experience, environmental concern and energy saving behavior, Energy Economics, 40, 953-966.

Badiani, R., & Jessoe, K. (2013). The impact of electricity subsidies on groundwater extraction and agricultural production. Department of Agriculture and Resource Economics Working Paper, University of California Davis, 1-41.

Bell, A. R., Shah, M. A. A., & Ward, P. S. (2014). Reimagining cost recovery in Pakistan's irrigation system through willingness-to-pay estimates for irrigation water from a discrete choice experiment. Water Resources Research, 50(8), 6679-6695.

Bertoldi, P., Rezessy, S., & Oikonomou, V. (2013). Rewarding energy savings rather than energy efficiency: Exploring the concept of a feed-in tariff for energy savings. Energy Policy, 56, 526–535.

Bhatia, R. (2007) Water and Energy Interactions. Handbook of Water Resources in India, Oxford University Press.

Bhattacharyya, S. C. (2012). Energy access programmes and sustainable development: A critical review and analysis. Energy for Sustainable Development, 16(3), 260-271.

Birner, R., Gupta, S., & Sharma, N. (2011). The political economy of agricultural policy reform in India: Fertilizers and electricity for irrigation (Vol. 174). Washington DC. International Food Policy Research Institute.

Blankenship, B., Wong, J. C. Y., & Urpelainen, J. (2019). Explaining willingness to pay for pricing reforms that improve electricity service in India. Energy Policy, 128, 459-469.

Bor, Y. J., Chien, Y. L., & Hsu, E. (2004). The market-incentive recycling system for waste packaging containers in Taiwan. Environmental Science & Policy, 7(6), 509–523.

Bose, R. K., & Shukla, M. (2001), Electricity tariffs in India: an assessment of consumers' ability and willingness to pay in Gujarat, Energy Policy, 29(6): 465–478.

Bryan, S., Buxton, M., Sheldon, R., & Grant, A. (1998). Magnetic resonance imaging for the investigation of knee injuries: an investigation of preferences. Health Economics, 7(7), 595- 603.

Burton, M., Cooper, B., & Crase, L. (2020), Analysing Irrigation Farmers' Preferences for Local Governance Using a Discrete Choice Experiment in India and Pakistan, Water, 12(6), 1821, 1-18.

Carlsson, F., & Martinsson, P. (2008), Does it matter when a power outage occurs?—A choice experiment study on the willingness to pay to avoid power outages, Energy Economics, 30(3), 1232-1245.

Casey, J. F., Kahn, J. R., & Rivas, A. (2006). Willingness to pay for improved water service in Manaus, Amazonas, Brazil. Ecological Economics, 58(2), 365-372.

Clements, M. B. J., Coady, M. D., Fabrizio, M. S., Gupta, M. S., Alleyne, M. T. S. C., & Sdralevich, M. C. A. (2013). Energy subsidy reform: lessons and implications. International Monetary Fund.

De la Rue du Can, S., Leventis, G., Phadke, A., & Gopal, A. (2014). Design of incentive programs for accelerating penetration of energy-efficient appliances. Energy Policy, 72, 56–66.

Dossani, R., & Ranganathan, V. (2004), Farmers' willingness to pay for power in India: conceptual issues, survey results and implications for pricing, Energy Economics, 26(3): 359 – 369.

Dubash, N. K. (2007). The electricity-groundwater conundrum: Case for a political solution to a political problem. Economic and Political Weekly, 45-55.

Farhar, B. C. (1999), Willingness to pay for electricity from renewable resources: a review of utility market research, National Renewable Energy Laboratory, NREL/TP, 550, 1-20.

Faruqui, A., Harris, D., & Hledik, R. (2010). Unlocking the€ 53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment. Energy Policy, 38(10), 6222-6231.

Fishman, R., Lall, U., Modi, V., & Parekh, N. (2016). Can electricity pricing save india's groundwater? Field evidence from a novel policy mechanism in Guj Journal of the Association of Environmental and Resource Economists, 3(4), 819-855.

Fishman, R., Devineni, N., & Raman, S. (2015). Can improved agricultural water use efficiency save India's groundwater?. Environmental Research Letters, 10(8), 084022, 1-10.

Fosli, J. K., Reddy, A. A., & Rani, R. (2021). The Policy of Free Electricity to Agriculture Sector: Implications and Perspectives of the Stakeholders in India. Journal of Development Policy and Practice, 6(2), 252-269.

Fujita, Y., Fujii, A., Furukawa, S., & Ogawa, T. (2005). Estimation of willingness-to-pay (WTP) for water and sanitation services through contingent valuation method (CVM): A case study in Iquitos City, The Republic of Peru. JBICI review, 11(March), 59-87.

Gagne, D. A., Settle, D. E., Aznar, A. Y., & Bracho, R. (2018). Demand Response Compensation Methodologies: Case Studies for Mexico (No. NREL/TP-7A40-71431). National Renewable Energy Lab, Golden, CO (United States), https://perma.cc/78MX-TKVX.

Gal, D., & Rucker, D. D. (2018). The loss of loss aversion: Will it loom larger than its gain?. Journal of Consumer Psychology, 28(3), 497-516.

Gajanan, S. N., Chandramohan, B. P., & Babu, N. S. (2014), Willingness to pay for reliable power in the presence of resource depletion: The case of groundwater and electricity in Tamil Nadu. International Journal for Public Policy, 118-134.

Gill, B., Saluja, S., & Palit, D. (2017). Electricity pricing and the willingness to pay for electricity in India: current understanding and the way forward. The Energy and Resources Institute: New Delhi, India.

Golden, M. A., & Min, B. (2012). Theft and loss of electricity in an Indian state. International Growth Centre.

Gulati, M., & Pahuja, S. (2012). Direct delivery of power subsidy to agriculture in India. Sustainable Energy for All.

Gulati, M., & Pahuja, S. (2015). Direct delivery of power subsidy to manage energy–ground water–agriculture nexus. Aquatic Procedia, 5, 22-30.

Gunatilake, H., Maddipati, N., & Patail, S. (2012), Willingness to Pay for Good Quality, Uninterrupted Power Supply in Madhya Pradesh, India, (South Asia Working Paper Series: 13). Philippines: Asian Development Bank (ADB).

Hanisch, M., Kimmich, C., Rommel, J., & Sagebiel, J. (2010), Coping with power scarcity in an emerging megacity: a consumers' perspective from Hyderabad, International journal of global energy issues, 33(3-4), 189-204.

Hindustan Times (2021) Power subsidy bill, arrears cross 10% of Punjab's total budget, May 29, 2021, Chandigarh India.

Honnihal, S. (2004). Estimating Power Consumption in Agriculture. Economic and Political Weekly, 790-792.

Huh, S. Y., Lee, J., & Shin, J. (2015), The economic value of South Korea ' s renewable energy policies (RPS, RFS, and RHO): A contingent valuation study, Renewable and Sustainable Energy Reviews, 50, 64-72.

Huenteler, J. T., Hankinson, D. J., Rosenthal, N., Balabanyan, A., Kochnakyan, A., Rana, A., & Foster, V. (2020). Cost recovery and financial viability of the power sector in developing countries: Insights from 15 case studies. World Bank Policy Research Working Paper.

Ito, K., Ida, T., & Tanaka, M. (2018). Moral suasion and economic incentives: Field experimental evidence from energy demand. American Economic Journal: Economic Policy, 10(1), 240–267.

Jack, B. K., Kousky, C., & Sims, K. R. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. Proceedings of the National Academy of Sciences, 105(28), 9465-9470.

Johl, S. S., Sidhu, R. S., & Vatta, K. (2014). Natural resources management in Punjab agriculture: challenges and way forward. Discussion Paper, Centre for International Projects Trust, New Delhi.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. Econometrica, 47, 263–291.

Kalkbrenner, B. J., Yonezawa, K., & Roosen, J. (2017), Consumer preferences for electricity tariffs: Does proximity matter?, Energy Policy, 107, 413-424.

Kennedy, R., Mahajan, A., & Urpelainen, J. (2019). Quality of service predicts willingness to pay for household electricity connections in rural India. Energy policy, 129, 319-326.

Kishore, A., & Verma, S. (2003). What determines pumping behavior of tube well owners: marginal cost or opportunity cost?. IWMI-Tata Water Policy Research Highlight, No. 6. IWMI-Tata Water Policy Program, Anand.

Komives, K., Foster, V., Halpern, J., & Wodon, Q. (2005). Water, electricity, and the poor: Who benefits from utility subsidies?. World Bank Publications.

Kumar, M. D., Scott, C. A., & Singh, O. P. (2011). Inducing the shift from flat-rate or free agricultural power to metered supply: Implications for groundwater depletion and power sector viability in India. Journal of Hydrology, 409(1-2), 382-394.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: analysis and applications. Cambridge University Press.

Planning Commission (2014). Annual report on working of State Electricity Boards and Electricity Departments. New Delhi, India.

Prasanna, A., Mahmoodi, J., Brosch, T., & Patel, M. K. (2018). Recent experiences with tariffs for saving electricity in households. Energy Policy, 115, 514–522.

Prayas (2018) Understanding the Electricity, Water and Agriculture Linkages – Volume I, Prayas Energy Group.

Mahmoodi, J., Hille, S., Patel, M. K., & Brosch, T. (2021). Using rewards and penalties to promote sustainability: Who chooses incentive-based electricity products and why?. Journal of Consumer Behaviour, 20(2), 381-398.

Mahmoodi, J., Prasanna, A., Hille, S., Patel, M. K., & Brosch, T. (2018). Combining "carrot and stick" to incentivize sustainability in households. Energy Policy, 123, 31-40.

Mitra, A., Balasubramanya, S., & Bouwer, R. (2021). Can electricity rebates modify groundwater pumping behaviours? Evidence from a pilot study in Punjab, India. 1-41.

Morris, S. (2001). Overexploitation of Ground Water Can Be Overcome by Correctly Pricing Electricity and Diesel. India Infrastructure Report 2001, pp. 270-271.

Mortazavi, S. A., Najafi Alamdarlo, H., & Zaghi Bijarbas, M. (2019). Estimating the eco-environmental value of damages caused by groundwater over drafting. International Journal of Environmental Science and Technology, 16(7), 3861-3868.

Mukherji, A., & Das, A. (2014). The political economy of metering agricultural tube wells in

West Bengal, India. Water international, 39(5), 671-685.

Nomura, N., & Akai, M. (2004). Willingness to pay for green electricity in Japan as estimated through contingent valuation method. Applied Energy, 78(4), 453-463.

OECD (2012). Farmer Behaviour, Agricultural Management and Climate Change. OECD Publishing Paris.

Ovo energy (2020) Terms for smart incentive offer from OVO, OVO Energy, 1 Rivergate, Temple Quay, Bristol BS1 6ED https://www.ovoenergy.com/terms/smart-incentive.

Ozbafli, A., & Jenkins, G. P. (2016). Estimating the willingness to pay for reliable electricity supply: A choice experiment study. Energy Economics, 56, 443-452.

PSPCL Commercial circulation (2022) Punjab State Power Corporation Limited, Patiala.

Rawat, S., & Mukherji, A. (2012). Poor state of irrigation statistics in India: the case of wells and tube wells. International Journal of Water Resources Development 30(2), 262-281.

Rehn, E. (2003), Willingness to Pay for Extra Services and Consumer Behaviour in the Swedish Electricity Market–A Contingent Valuation, Unpublished. M.Sc. Thesis, Lunds University Sweden.

Richter, L. L., & Pollitt, M. G. (2018). Which smart electricity service contracts will consumers accept? The demand for compensation in a platform market. Energy Economics, 72, 436-450.

Roe, B., Teisl, M. F., Levy, A., & Russell, M. (2001). US consumers' willingness to pay for green electricity. Energy Policy, 29(11), 917-925.

Ryan, M., Kolstad, J. R., Rockers, P. C., & Dolea, C. (2012), How to conduct a discrete choice experiment for health workforce recruitment and retention in remote and rural areas: a user guide with case studies (No. 74489, pp. 1-94). The World Bank.

Ryan, M., Gerard, K., & Amaya-Amaya, M. (Eds.). (2007). Using discrete choice experiments to value health and health care (Vol. 11). Applied Health Economics and Health Policy 2(1), 55-64.

Ryan, M., & Hughes, J. (1997). Using conjoint analysis to assess women's preferences for miscarriage management. Health Economics, 6(3), 261-273.

Sagebiel, J., & Rommel, K. (2014), Preferences for electricity supply attributes in emerging megacities—Policy implications from a discrete choice experiment of private households in Hyderabad, India. Energy for Sustainable Development, 21, 89-99.

Saleth, R. M. (1997). Power Tariff Policy for Groundwater Regulation: Efficiency. Equity and Sustainability. Artha Vijnana, 39, 312-322.

Santhakumar V (2008), Analysing Social Opposition to Reforms: The Electricity Sector in India, SAGE Publications, India.

Shultz, S. D., & Lindsay, B. E. (1990). The willingness to pay for groundwater protection. Water Resources Research, 26(9), 1869-1875.

Sidhu, B. S., Kandlikar, M., & Ramankutty, N. (2020). Power tariffs for groundwater irrigation in India: A comparative analysis of the environmental, equity, and economic tradeoffs. World Development, 128, 1-13.

Singh, K. (2012). Electricity subsidy in Punjab agriculture: Extent and impact. Indian Journal of Agricultural Economics, 67(4), 617-632.

Siyaranamual, M., Amalia, M., Yusuf, A., & Alisjahbana, A. (2020). Consumers' willingness to pay for electricity service attributes: A discrete choice experiment in urban Indonesia. Energy Reports, 6, 562-571.

Shah, T., Scott, C., Kishore, A., & Sharma, A. (2004). Energy-irrigation nexus in South Asia: Improving groundwater conservation and power sector viability (Vol. 70). International Water Management Institute, Colombo Sri Lanka.

Shah, T., Giordano, M., & Mukherji, A. (2012). Political economy of the energy-groundwater nexus in India: exploring issues and assessing policy options. Hydrogeology Journal, 20(5), 995-1006.

Slavin, R. E., Wodarski, J. S., & Blackburn, B. L. (1981). A group contingency for electricity conservation in master-metered apartments. Journal of Applied Behavior Analysis, 14(3), 357-363.

Stern, P. C. (1999). Information, incentives, and proenvironmental consumer behavior. Journal of Consumer Policy, 22(4), 461–478.

Sun, C., & Lin, B. (2013). Reforming residential electricity tariff in China: Block tariffs pricing approach. Energy Policy, 60, 741-752.

Sudarshan, A. (2017). Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. Journal of Economic Behavior & Organization, 134, 320-335.

Timlett, R. E., & Williams, I. D. (2008). Public participation and recycling performance in England: A comparison of tools for behaviour change. Resources, Conservation and Recycling, 52(4), 622–634.

Tongia, R. (2003). The political economy of Indian power sector reforms. Program on Energy and Sustainable Development Working Paper 4(1), 1-10.

Vo, D. T., & Huynh, K. V. (2017). Estimating residents' willingness to pay for groundwater protection in the Vietnamese Mekong Delta. Applied Water Science, 7(1), 421-431.

Williams, J. H., & Ghanadan, R. (2006). Electricity reform in developing and transition countries: A reappraisal. Energy, 31(6-7), 815-844.

Winett, R. A., Kagel, J. H., Battalio, R. C., & Winkler, R. C. (1978). Effects of monetary rebates, feedback, and information on residential electricity conservation. Journal of Applied Psychology, 63(1), 73-80.

Wiser, R. H. (2007), Using contingent valuation to explore willingness to pay for renewable energy: a comparison of collective and voluntary payment vehicles, Ecological Economics, 62(3-4), 419-432.

Wolak, F. A. (2010). An experimental comparison of critical peak and hourly pricing: the PowerCentsDC program. Department of Economics Stanford University. https://web.stanford.edu/group/fwolak/cgibin/sites/default/files/files/An%20Experimental%2

0Comparison%20of%20Critical%20Peak%20and%20Hourly%20Pricing_March%202010_Wolak.pdf

Xiqin, W., Xinyue, Z., Hao, C., & Ying, C. (2022). Overuse-charge agricultural water price mechanism in groundwater overdraft areas. Water Policy, 24(1), 132-144.

Zekri, S. (2008). Using economic incentives and regulations to reduce seawater intrusion in the Batinah coastal area of Oman. Agricultural Water Management, 95(3), 243-252.

Figure 4:13 Studies on Willingness to pay

Authors	Study Area	Results
Bose and Shukla et al (2001)	700 consumers comprising 208 urban households, 285 farmers, 47 HT industries and 156 LT industries in Gujarat, India from September – November 1997	A questionnaire-based socio-economic sample survey was used to estimate willingness to pay for electricity by estimating the costs of meeting energy needs by alternative sources.
Gajanan and Chandramohan (2014)	450 farmers in Tamil Nadu, India	Contingent valuation methodology was used to present results for farmers' willingness to pay for reliable power.
Kennedy et al (2019)	714 villages of 8500 rural households from six States	2014-15 ACCESS survey data was used to show importance of high quality of service for willingness to pay. Three different measures of quality of electricity service were - daily total hours available, hours available at night, and a quality index considering outages and voltage fluctuation.
Hanisch et al. (2010)	142 households in Hyderabad	Majority of sampled households preferred quality improvements of power supply over increases in delivered quantity.
Sagebiel and Rommel (2014)	798 urban consumers in Hyderabad	Discrete choice experiment to evaluate four criteria of power-availability of electricity, external effects of power generation, organization of power sector, and costs for improved electricity quality. Household preferences are highly heterogeneous. Limited preparedness of domestic users to pay for improved electricity quality and renewable energy. Households prefer state owned distribution companies to private enterprises or cooperative societies.
Dossani and Ranganathan (2004)	449 respondents in 84 villages of three agro-climatic zones of Andhra Pradesh in 2000	Strategies for raising prices of rural power were examined. Discriminatory pricing regime such as 50 percent price rise for those with motors exceeding 15HP could raise revenues by 20 percent. Average pumpset burnout was 1.59 a year and effect of removing causes of burnout was positive. Eliminating rostering was seen to lead farmers to use 15.5% less power, thereby reducing subsidy burden.
Gunatilake et al (2012)	2083 households from 40 Gram Panchayats (GPs) from two districts of MP namely Rajgarh and Guna in MP	Contingent valuation method estimated high WTP of rural households to receive 24-hour, good quality supply, with accurate billing and good customer service. Revealed preference methods are likely to underestimate benefit of improved electricity service. Block tariffs can induce energy conservation

Gill et al (2017)	Meta analysis of 98 willingness to pay studies in India	Existing willingness to pay assessments are insufficient to fill the per unit gap between distribution utility's average cost of supply and realized revenues. Parallel action along three measures - reduction in AT&C losses, conversion of unmetered to metered connections and increasing hours of supply would be required to effectively reduce the gap.
Blankenship et al (2019)	1920 rural and urban respondents from 12 districts in Uttar Pradesh	Non-financial considerations shape popular support for electricity pricing reforms. Respondents with more social trust were willing to pay more. Delays in service improvement and lack of community support reduce willingness to pay. Sense of entitlement was found to be a low indicator of willingness to pay.
Santhakumar (2008)	7000 households in 4 States in India	Willingness to pay for electricity and opposition to electricity reform depended on current level of service and varies within and between states in India.
Abdullah and Mariel (2010)	202 respondents from electrified households in Kisumu, Kenya	Willingness to pay for electricity service reliability was measured. Reliability was measured by number of planned blackouts and duration of outage. Attributes were duration and frequency of outages, type of distribution provider, and costs of electricity consumption. Socio-economic and demographic characteristics explain preference heterogeneity. Bank holders, farmers and large family households preferred to pay more for reliable supply, while unemployed, older and longer residents in the area were disinclined to pay more than their monthly bill for improved service reliability.
Amador et al. (2013)	73 respondents in Canary Islands, Spain	Five attributes were selected - Monthly household electricity bill, number of non-scheduled outages per year, outages average length in minutes, electricity generated from renewable energies (%) and energy audit WTP to reduce outage frequency is positively correlated with customers' experiences on serious outages. WTP for renewable energies is positively correlated with customers' education level and concern for the greenhouse gases (GHG) emissions.
Carlsson and Martinsson (2008)	473 Swedish consumers	Higher WTP was observed for avoiding a power cut during weekends in winter. WTP displayed increasing values with duration of power cut. Respondents living in big cities and in detached or terraced houses were found to have lower WTP to reduce power cuts.
Akcura (2011)	1019 respondents in EPRG survey 2006 and 2000 respondents in EPRG survey 2008	Information provided in the survey led to a higher willingness to pay for avoidance of blackouts than water disruptions. Information affects WTP only if the service attribute in question has personal relevance to

		respondent. If information is cognitively demanding, then it may lead to information overload and thus result in information being ignored. The results highlighted the role of demographic, behavioral and attitudinal variables on influencing willingness to pay. Level of income influenced willingness to pay, effect of price sensitivity index was negative, age also had a negative effect on willingness to pay and effect of gender was insignificant. The number of disruptions had a positive impact on willingness to pay. Energy efficiency action, degree of environmentalism, level of concern for climate change and awareness had a positive effect on willingness to pay. Respondents' level of concern for UK's increasing energy dependence on foreign fuel sources was significant.
Phadke et al (2019)	Bihar and Uttar Pradesh	Superefficient lamps, TVs, and fans can reduce energy consumption of rural household by over 70% cost, resulting in reduction in subsidy burden. Reduced consumption can offer an opportunity to raise tariffs while keeping monthly bills reduced. Super-efficient appliances also lead to higher willingness to pay.
Siyaranamual et al (2020)	1502 respondents in Bandung, Indonesia	Electricity service was defined with the help of four attributes: rural electrification, frequency of outage per year, hydropower for electricity generation, and monthly electricity bill. Share of consumers willing to pay for electricity improvement was high. All non-monetary attributes were important. Increased monthly electricity bills can potentially finance electricity improvements.
Richter and Pollitt (2016)	1892 respondents in UK	Six choice attributes selected were: (i) monitoring of energy usage, (ii) control of electricity usage, (iii) technical support with set-up and usage, (iv) data privacy and security services (v) expected electricity savings, and (vi) fee for service bundle. Flexible mixed logit model was combined with posterior analysis to elicit consumer preferences and heterogeneity in valuations for smart electricity services. The findings of the study were - Customer profiling based on posterior analysis could inform smart contract design; Mixture of fixed and transaction-based payment to the consumers could promote acceptance of smart electricity services contracts; Scope for customer specific contract design to cater to preferences different from other customer clusters.
Ozbafli and Jenkins (2016)	350 interviews in North Cyprus	Attributes selected were: i) frequency of outages; (ii) duration of outages; (iii) time of outages; (iv) prior

		notification; and (v) percentage change in monthly electricity bill. There is a demand for electricity service reliability. Reliability is measured by the frequency, duration, time, and prior notification of outage. The annualized economic benefits would justify an investment in additional generation capacity to eliminate the service reliability problem.
Huh et al. (2015)	500 adult respondents in Seoul, South Korea	Electricity mix, smart meter installation, number of blackouts, duration of blackouts and social contribution of electric company were five attributes. Customers' willingness to pay for significant increase in renewable energy was far less than the cost of achieving it. Electricity bill and electricity mix were the two most important attributes in electricity service.
Burton et al (2020)	819 respondents from India and Pakistan	Examined preferences of irrigation farmers for different payment apparatus for irrigation fees. "Payment" choice experiment had four attributes covering: basis of charging, assessment method, payment method and collection method. "Governance" choice experiment comprised of three attributes: share of irrigation fees kept locally sanction for non-compliance with rules, and method of maintaining local irrigation system. Aligning payment mechanisms and local water governance more closely with farmer preferences is likely to reduce barriers to accepting participatory irrigation and requirement to pay water charges
Kalkbrenner et al. (2017)	953 residential energy customers in Germany	Shares of regional generation, power providers, and electricity mixes were selected attributes. Electricity bill and electricity mix were the two most important attributes in electricity service. There is no indication that consumers were willing to pay for higher shares of regional generation.
Goett et al (2000)	1205 customers in US	More than 40 attributes including sign-up bonuses, amount and type of renewables, billing options, bundling with other services, reductions in voltage fluctuations, and charitable contributions were selected. Consumers, on average were willing to pay extra for supplier that has 25% hydro power relative to a supplier with no renewables. Consumers only focus on the use of hydro in the electricity generation rather than the impact of hydro on the environment.
Contingent valuation		

studies		
Abdullah and Jeanty (2011)	200 households in Kisumu, Kenya	Respondents were willing to pay more for grid electricity services than solar power and households favored monthly connection payments over a lump sum amount
Nomura and Akai (2004)	370 households in Japan	Japanese households were willing to pay more, in the form of a flat monthly surcharge, for renewable energy. The median value of willingness to pay for renewable energy was estimated at about 2000 yen ($17) per month per household.
Wiser (2007)	1574 residents in US	Explored willingness to pay (WTP) for renewable energy under collective and voluntary payment vehicles, under government and private provision. Study found some evidence that when confronted with a collective payment mechanism, respondents stated a somewhat higher willingness to pay than when voluntary payment mechanisms were used. Private provision of the good elicited a somewhat higher willingness to pay than government provision.
Farhar (1999)	14 different surveys in 12 utility service territories in five Western/Southwestern states in US	Willingness to pay for renewable energy followed a predictable pattern with an average majority of 70% willing to pay at least $5 per month more for electricity from renewable sources, 38% willing to pay at least $10 per month more, and 21% willing to pay at least $15 more per month.
Rehn (2003)	Sweden	CV survey examined the WTP for three extra services – internet energy saving advice, personal energy saving advice and an insurance service – all supplied by electricity companies in the Swedish electricity market. The average willingness to pay for all three services was low, in fact, well below $.99 (10 SEK) per quarter of the year.
Roe (2001)	1001 adults from 8 US cities	US consumers' willingness to pay was analyzed for energy related air pollution reduction. Results suggested that many population segments were willing to pay for decreased air emissions even if there was no alteration in fuel source.

Figure 4:14 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*

Questionnaire 3

1 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1500 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 2/kWh is

paid for each saved unit within the allowed limit, and Rs. 1/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

2 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1500 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 3/kWh is paid for each saved unit within the allowed limit, and Rs. 1/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

3 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1550 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 2/kWh is paid for each saved unit within the allowed limit, and Rs. 1/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

4 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1550 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 3/kWh is paid for each saved unit within the allowed limit, and Rs. 1/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

5 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1500 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 2/kWh is

paid for each saved unit within the allowed limit, and Rs. 2/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

6 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1500 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 3/kWh is paid for each saved unit within the allowed limit, and Rs. 2/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

7 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1550 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 2/kWh is paid for each saved unit within the allowed limit, and Rs. 2/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

8 On average 1500-1550 kWh units of electricity are required for one acre land. There can be a scheme where an annual limit of 1550 kWh of free electricity units per acre is offered to the farmer. Cash incentive of Rs. 3/kWh is paid for each saved unit within the allowed limit, and Rs. 2/kWh electric charge is levied on consumption beyond limit. As meter would be necessary to avail the cash incentive, reward of Rs. 20/quintal on annual farm output could be offered to the farmer to motivate him for meter installation, would you accept such a scheme?
Yes or No

Or would you prefer to stay with the existing scheme of free electricity without any cash incentive or annual free electricity limit?
Yes or No

9 What rate of electricity charge would you be willing to pay in case you are offered cash reward of Rs. 20/q on annual farm output? There would be free unlimited supply of electricity and no cash incentive for saving electricity.

(a) Rs.0.25/kWh

(b) Rs.0.50/kWh

(c) Rs.0.75/kWh

10 What rate of electricity charge would you be willing to pay in case you are offered cash reward of Rs. 24/q on annual farm output? There would be free unlimited supply of electricity and no cash incentive for saving electricity.

(a) Rs.0.50/kWh

(b) Rs.0.75/kWh

(c) Rs.1/kWh

11 What rate of electricity charge would you be willing to pay in case there is annual limit of free 1500 kWh/acre units of electricity? There would be no offer of cash incentive for saving electricity or cash reward of Rs. 20/q on farm output.

(a) Rs.0.25/kWh

(b) Rs.0.50/kWh

(c) Rs.0.75/kWh

12 What rate of electricity charge would you be willing to pay in case there is annual limit of free 1550 kWh/acre units of electricity? There would be no offer of cash incentive for saving electricity or cash reward of Rs. 20/q on farm output.

(a) Rs.0.25/kWh

(b) Rs.0.5/kWh

(c) Rs.0.75/kWh

13 What rate of electricity charge would you be willing to pay in case there is annual limit of free 1500 kWh/acre units of electricity and cash incentive of Rs. 1/kWh for saving electricity?

(a) Rs.0.25/kWh

(b) Rs.0.5/kWh

(c) Rs.0.75/kWh

14 What rate of electricity charge would you be willing to pay in case there is annual limit of free 1550 kWh/acre units of electricity and cash incentive of Rs. 1/kWh for saving electricity?

(a) Rs.0.25/kWh

(b) Rs.0.5/kWh

(c) Rs.0.75/kWh

Other questions

1. Is there a problem of groundwater depletion? Do you face any difficulty in irrigating your crop?
Yes or No

2. Did you have to dig deeper to get water in the last ten years?

Yes or No

3. Do you know that Central Ground Water Board has predicted that ground water will get depleted in 25 years? If this happens, your future generations will not get water easily. What should be done to conserve water now?
Answer

4.How can groundwater be saved? What should farmers do to save groundwater and energy?
Yes or No

5.Do you think Government should make laws to discourage wastage of water?
Yes or No

6.Do you think use of electricity should be regulated by installing meters?
Yes or No

7.Please give any other suggestion for conserving water and electricity?
Answer

8.There are various ways to conserve water. What is your opinion about direct seeding of rice?
Answer

9.If farmer is given quota of free electricity with pre-paid meter and provided information on unutilized electricity, do you think he will become more mindful of wastage/consumption? What is your opinion?
Answer

5. Chapter: Farmers preferences for incentives on solar pumps: Evidence from a choice experiment in Punjab

5.1: Introduction

With the world's third largest electricity sector and ambitious emission targets, large-scale deployment of renewable energy offers an opportunity to decarbonize electricity systems in India (Shah, 2021). Fossil fuel remains the predominant force in India's power sector, contributing 60 percent of total installed capacity (Ministry of Power 2021). Solar energy accounts for a mere 3 percent of annual electricity generation. Indian agriculture is significantly dependent on irrigation with 30 percent relying on it and 60 percent of irrigation demand being met by groundwater (India Energy Outlook 2021). With 21 percent of the total electricity consumption, decarbonizing electricity systems in the agriculture sector is necessary to reduce greenhouse gas emissions and over-dependence on fossil fuels.

There are interlocking challenges of the water-energy nexus in agriculture. Solar pumps can be a potential game-changer in extending the electricity transmission network, replacing expensive diesel pumps, and addressing the issue of depleting groundwater (ICID 2019). Solar energy can offer a reliable, affordable, and clean alternative to the coal-driven electric irrigation pumps which consume the highest State subsidies in Indian agriculture. Therefore, central and state governments increasingly pitch for solar-powered irrigation pumps in India. There has been a steady decline in the cost of solar PV panels, and expansion in subsidy schemes. The government uses several support programs for giving substantive capital subsidies and attractive buyback rates to incentivize adoption. Despite the government's subsidy programs and increasing focus on solar energy use in agriculture, the majority of the irrigation needs are still being met by electric or diesel-operated pumps. The adoption of agriculture solar pumps remains a significant challenge.

One of the possible reasons for slow adoption is that policy decisions are taken by the government and adoption decisions are taken by the farmer who may be using different assessment criteria. This study emphasizes the need for understanding preferences for different incentives to make solar pumps affordable and attractive options for farmers. Punjab has vast solar generation capacity but achieving the potential will require improved policies. A discrete choice experiment is conducted to determine how the acceptability and response behavior of Punjab farmers for solar pumps and feeder-level solarization is likely to vary as a result of different incentives. The stated preference elicitation method is appropriate to evaluate potential behavioral responses to policy interventions.

The paper is organized in six sections: Section 5.2 presents a description of the problem. Section 5.3 reviews the relevant literature. Section 5.4 discusses the discrete choice methodology applied in this study. Section 5.5 contains the empirical results. Section 5.6 discusses the results and policy implications, and Section 5.7 offers conclusions.

5.2: Description of problem

A variety of stimulating policies and tools have been offered to accelerate solar photovoltaic adoption in India. Expanding solar irrigation has been a huge challenge even though the Indian government is promoting them by offering huge subsidies. Off-grid solar PV pumps were one of the oldest programs of the Ministry of New and Renewable Energy aimed at providing solar PV based applications in areas where grid power was either not available or unreliable. The government offered sixty percent subsidy for installing off-grid solar pumps in 22 water-safe blocks (administrative units) in Punjab (Punjab Energy Development Agency 2020). Against a target of 12000 standalone solar pumps, 6192 solar pumps have been installed in Punjab (Ministry of New and Renewable Energy, 2022b).

A more recent policy, referred to as component C of the central government's PM-KUSUM scheme offered solarization of existing grid-connected agriculture pumps in 2019-20 in a pilot mode (Ministry of New and Renewable Energy, 2019). Under the scheme, individual farmers having grid-connected agriculture pumps were offered sixty percent subsidy to solarize pumps. Central and State governments were to equally provide subsidies to cover sixty percent of the cost of the grid-connected solar pump. The scheme was designed to help farmers use the generated solar power to meet their irrigation needs and excess solar power was to be sold to the electric utility at a pre-defined tariff. In addition to the Central government's KUSUM scheme offering sixty percent subsidy on the cost of a solar pump, different state governments complemented these initiatives by hiking the subsidy component and offering attractive buyback or feed-in-tariff rates. Some state governments enhanced their share of the subsidy to encourage higher adoption. State governments were mandated to determine the levelized tariff for the purchase of surplus solar energy from solar pump-owning farmers in their respective states.

Accordingly, Punjab State Electricity Regulatory Commission determined the tariff of Rs. 2.60/kWh ($0.032/kWh) in 2020 for the purchase of surplus power generated by the proposed 3900 grid-connected irrigation pumps to be installed with the support of state subsidy (solar PV array of 4 KW for 3 HP capacity Pump, 7 KW for 5 HP and 10 KW for 7.5 HP) in Punjab after meeting power requirements for irrigation of agriculture land (Punjab State Electricity Regulatory Commission 2020). However, the policy of offering sixty percent subsidy on individual grid-connected agriculture solar pumps was not fully implemented in Punjab.

During the pilot stage, following a third-party evaluation of the scheme conducted by the central government, the scheme was amended in December 2020 to include feeder-level solarization as a new variant of the existing grid-connected agriculture pumps. The central government withdrew sanctions for solarization of 3900 individual grid-connected agriculture pumps and issued fresh sanctions of 25000 grid-connected agriculture pumps under feeder-level solarization in Punjab for setting up centralized solar power plants supplying power to agriculture feeders (Ministry of New and Renewable Energy, 2022a). The new policy involves setting up a solar plant of adequate capacity to supply power to agriculture feeders or multiple feeders instead of installing solar panels on individual pump. The scheme for subsidizing individual grid-connected solar pumps has, therefore, been replaced by the new variant of feeder-level solarization policy in Punjab and the government is engaged in finalizing plans for the design, installation, and commissioning of feeder-level solar plants (Punjab Energy Development Agency 2022). 65 agriculture feeders have been identified for solarization of 25000 grid- connected agriculture pumps under the feeder-level solarization scheme.

Under the new scheme guidelines, developers are eligible to draw 30 percent central financial assistance for setting up solar power plants and would be selected based on the lowest tariff offered for the supply of required solar power for 25 years. The ceiling tariff of Rs. 2.78/kWh initially determined for the selection of developers was considered to be very low as there was low participation in the bidding process. Only three applications for 1 MW capacity each were received for a cumulative capacity of 3 MW against the allocated target of 220 MW. The regulator recognized that the tariff is higher in neighboring states – Rs. 3.98/kWh in Himachal Pradesh, Rs. 3.11/kWh in Haryana, and Rs. 3.14/kWh in Rajasthan. Therefore, the levelized tariff was revised to Rs. 2.997/kWh (Punjab State Electricity Regulatory Commission April 2022). It is argued that the burden of electricity subsidy would be reduced to the extent of the difference in the rate of solar power supply by the developer and the present cost of power delivered by the utility at the distribution substation.

With the policy shift from giving subsidies to farmers for the installation of individual grid-connected pumps to granting a subsidy to the state government for feeder-level solarization programs, it becomes necessary to evaluate farmers’ preferences for different institutional models of solar irrigation systems. It is important to comprehensively examine factors influencing farmers' preferences that can hinder or support the adoption of solar irrigation systems.

Punjab has been chosen for this analysis as it is one of the worst affected States in terms of over-stressed groundwater resources and unsustainable levels of electricity subsidies for irrigation. Punjab is one of the nine Indian States witnessing a critical groundwater situation, both in terms of falling availability and deteriorating water quality. The subsidized or free power is responsible for the rapid depletion and overexploitation of groundwater resources (Baweja et al., 2017). Free electricity to irrigate farmers' fields has prompted excessive pumping, besides indirectly causing soil degradation, soil nutrient imbalance, and increased carbon emissions. There is a growing realization about the degradation of land, water, and environment due to the current pattern of agricultural production and its sustainability is under question (Chand, 1999). The huge economic and environmental cost of electricity subsidies has led to serious thought about reforming the prevailing subsidy regime. Solarization is perceived as an innovative approach to solve the invidious energy-water nexus. Although many studies have explored the public acceptance of renewable energies, very few studies have analyzed public willingness and attitudes towards government incentives to increase solar photovoltaic penetration. To address this question, a discrete choice experiment has been conducted to examine whether individual-owned grid-connected solar pumps can serve as an effective alternative to the highly subsidized electric pumps in Punjab agriculture.

As prices of solar PV pumping are expected to fall in real terms in future, PV pumping would become accessible to more of the poorest communities. This would present a risk to water resources. In this context of falling cost of solar technologies in the future, grid connected solar pumps can serve as an effective tool to prevent water exploitation, propagate sustainable irrigation practices with increased revenues for farmers. Efforts to take advantage of abundant solar resources have prompted India to adopt auctions to reduce cost of support for solar PV. Solar PV water pumps without batteries are cheaper and are more economical. Reduction in the cost of battery storage would pave the way for solar PV dominated water pumping systems in Indian agriculture. Adopting the correct deployment model would help in moving away from electric/diesel pumps and have the desired impact on water conservation.

5.3: Review of Literature

5.3.1: Development of solar irrigation

There is large academic literature establishing that subsidies are essential to accelerate solar deployment. Given the high cost of solar photovoltaic (PV) installation, Shao and Fang (2021) found that government subsidies were conducive to the development of the PV industry. Feed- in tariffs and R&D subsidy policies were found to have a positive impact on PV system installation. The government offered 50 percent of the initial investment subsidy to grid-connected PV power generation and 70 percent of the initial investment subsidy to off-grid systems in China (Wang 2020). Lump-sum subsidy and concession projects were suggested as the main channels for investment in large-scale PV power in the future until the cost of PV systems became relatively steady (Zhang et al., 2012). Feed-in tariffs were more effective than alternative support schemes in promoting renewable energy technologies. Lesser and Su (2008) proposed an innovative two-part FIT (feed-in-tariff), consisting of both a capacity payment and a market-based energy payment to support PV energy technologies. Evidence from the top ten global solar power producers shows that government subsidies are effective PV development instruments. These countries are mainly depending upon instruments like a feed-in tariff, net metering, quotas with green certificates, low-interest bank loans, renewable portfolio standards, country's national renewable energy targets, investment tax credit, market premiums, and reverse auctions for the development of solar energy (Sahu 2015). Continued development of the renewable energy economy is dependent upon government support (Moosavian et al., 2013), and further financial support has been suggested to be made available to reinforce distributed PV adoption (Zhai 2013).

This study deals with relevant issues about incentives for promoting solar energy in Indian agriculture. One particular scheme or model may not fit all the states. The varying structures and dynamics of agriculture, power, and water systems across states pose huge challenges for implementation (Shah 2021). Some of the existing models applied in India are limiting greenhouse gas emissions, while some are leading to the dwindling of groundwater (Shirsath et al., 2020). There are two modalities for solarisation of pumps in India viz, (i) Net-metering: in this case, the agriculture pump continues to run at rated capacity taking power from solar panels and balancing power from the grid, if required, and in case solar power generation is higher than required by pump, the additional solar power is fed to the grid; (ii) Pump to run on solar power only: in this case, the pump runs on solar power as in the case of stand-alone off-grid solar pump and no power is drawn from the grid for the operation of the pump. In case solar power generation is higher than that required by the pump, the additional solar power is fed to the grid (Punjab State Electricity Regulatory Commission (2020).

Individual-owned solar agriculture pumps offer diverse benefits but impose costs as the environmental trade-offs with groundwater depletion present challenges for water use. It is argued that the opportunity cost of using power for groundwater is zero if there is no buyback of surplus power and no provision for storage. Farmers are likely to increase groundwater extraction or sell power to neighboring farmers. The energy buyback option gives solar energy for irrigation needs and generates additional income for farmers (Shah 2018). A second method of utilizing surplus solar power could be the use of battery storage (Gupta 2020), which may be very costly. Raising the opportunity cost of using solar power for groundwater extraction can influence groundwater pumping behavior. Solar energy farming with a power purchase agreement option can create opportunity cost of inefficient or wasteful use of solar energy and reduce water pumping (Al-Saidi and Lahhman, 2019).

However, an unintended consequence of paying higher subsidies to sell electricity may be that solar homes supply less power back to the grid. A household with a high feed-in tariff would consume less because of the substitution effect but they might consume more because of the income effect. With the increase in solar production, the income effect was found to dominate the substitution effect. Thus, as feed-in tariffs rise, consumption may increase whilst sales may decrease. Mechanisms that separate income effects from realized electricity production and exports, such as lump sum installation subsidies, maybe a more efficient way to support solar energy (La Nauze 2016). Households while exporting solar energy to the grid are not inattentive to the opportunity cost and do not treat solar generation as free. The purchase of excess power changes the opportunity cost of consumption while generating income. This has implications for regulating groundwater extraction through grid-connected solar pumps.

Compensation for excess electricity can be given in energy or monetary terms (Tongsopit et al., 2019). The one-to-one offset policy allows the offset of every 1 kWh produced by the solar rooftop PV system to the consumer with 1 kWh consumed from the grid (Husain et al., 2021). Applying the same analogy, offsetting residential bills with the solar power fed into the grid from an agriculture solar pump could be economically attractive and encourage water-saving behavior. An option to exchange surplus solar power with reductions in domestic electricity bills is expected to incentivize reduced pumping of water. Therefore, this study would also examine farmers' preferences for banking surplus solar power either as a cash payment or as a credit used to offset consumed units in the residential bill.

5.3.2: Discrete choice experiments

Discrete choice modeling has been employed extensively to study intentions to adopt new technologies, including solar photovoltaic systems. Due to the reduced installation cost and rapid advances in solar energy technology, there is huge interest among policymakers and scholars to elicit consumer preferences for solar energy. Several discrete choice experiments have identified key features important to the adoption of technologies such as solar photovoltaic panels, and sensitivity of adoption to policy incentives. Islam and Meade (2013) found that the expected utility of households behaved intuitively to the cost of installation, energy cost saving, increase in emissions, and payback time. It was suggested that education campaigns should go beyond the explanation of the technology and explain more about investment criteria, feed-in tariffs, and environmental effects. Yamaguchi et al., (2013) found that the policy measures for the diffusion of photovoltaics that reduce initial cost (e.g., subsidy programs) were more cost-effective for reducing CO2 emission than those reducing users' operating expenditure (e.g., feed-in tariff programs).

Lobel and Perakis (2011) demonstrated that it was optimal for the government to provide strong subsidies in the early stages of the adoption process, which take advantage of network externalities to reach the target adoption level at a lower cost. They showed that the current subsidy policy in Germany was not efficiently managed; raising early subsidies, and lowering future subsidies was a better way to achieve the target. Babich et al., (2020) compared the feed-in-tariff policy in Germany and the tax rebate policy in the US. They suggested that the government should prefer the feed-in-tariff policy when the electricity price is highly variable. The tax rebate policy should be adopted if the households are heterogeneous in generating efficiency, the investment cost is highly variable, and price and cost uncertainty is positively correlated.

Federal and state government incentives, in the form of financial rebates, have been a major strategy to accelerate the uptake of solar PV and solar hot water systems in Australia. Higgins et al., (2014) demonstrated that a feed-in tariff was a more effective incentive compared to a rebate on upfront cost, particularly in the adoption of larger PV units. The introduction of over-generous feed-in tariff regimes, followed by rapid reduction and in some cases cessation of this support mechanism was a factor for the limited success of the residential solar policy initially in Australia (Chapman et al., 2015). Financial support and general problem awareness were found to be critical, but the (strong) positive effects of information meetings, technical support meetings, and social networks were also identified as consumer motives for adopting photovoltaic systems in Groningen in the Netherlands (Jager 2006).

Studies have estimated consumers' willingness to pay for renewable energy technologies. Yoo and Kwak (2009) found that the willingness to pay for green electricity ranged from \$1.8/month to \$2.2/month and higher-income respondents were more likely to accept a given bid. Scarpa and Willis (2010) suggested that the British government would have to give substantially larger grants than those currently available if it was to induce significantly more households to install micro-generation technologies. Renewable energy adoption was significantly valued by households, but the value was not sufficiently large, for the vast majority of households, to cover the higher capital costs of micro-generation energy technologies, and to annual savings in energy running costs. Cicia et al., (2012) found a positive willingness to pay for solar and wind energy among Italian households. Borchers et al. (2007) found willingness to pay for green electricity, with a preference for solar over generic green and wind energy.

Studies have explored consumer preferences for service attributes of solar energy. Graber et al., (2018) found that consumers emphasize having electricity at the specified times and, more importantly, at times when they tend to use the service, instead of simply having higher amounts of electricity available with no understanding of timing. They were willing to pay higher prices for reliability and did not prioritize continuous power provision unaccompanied by corresponding reliability guarantees, rather rural consumers valued electricity reliability, specifically in the evening hours. Sandwell et al., (2016) suggested that a hybrid system, with solar power and battery storage meeting daytime demand and higher-capacity diesel or biomass-powered generation meeting demand during evening peaks and winter months, would satisfy demand more effectively in unelectrified households.

Choice experiments have been conducted to investigate consumer preferences for financial incentives offered for other energy-saving technologies. Wasi and Carson (2013) found that the water heater rebate program in New South Wales was successful in increasing the number of solar and heat pumps installed in the residential sector. Rouvenin and Matero (2013) emphasized the role of the investment cost as the main attribute affecting private homeowners' choice of residential heating system, although non-financial attributes also had a considerable effect.

Consumers' preferences and willingness to pay decisions are affected by socioeconomic and demographic characteristics. Batley et al., (2001) demonstrated that willingness to pay for renewable energy varied with social status and income. Zarnikau (2003) reported that age, education, and salary affected the willingness to pay for utility investments in renewable energy and energy efficiency resources. Intensive exposure to information about energy resource issues led to an increase in the number of respondents interested in paying a modest premium to support these investments. The probability of support for wind power decreased with age and income. However, people with an interest in environmental issues were more likely to be positive toward wind power (Ek 2005). A choice experiment conducted to elicit willingness to pay found that women and individuals having more than elementary education demanded less compensation for change from coal to hydropower production (Navrud and Braten 2007).

The focus of many studies has been on investigating preferences for green energy sources and identifying consumers' motivations and barriers to the adoption of renewable energy, including solar energy in developing countries. However few studies have explored policies that can motivate the adoption of solar technology in agriculture. A discrete choice experiment has been conducted to analyze the effectiveness of different policy instruments, ranging from the feed-in-tariff rate for buyback of surplus solar power to upfront capital subsidy on the cost of solar agriculture pumps, and from the individual-owned pump to feeder-level solarization in accelerating penetration of solar technology in agriculture. The focus was on investigating farmers' preferences for different forms of financial incentives, particularly the importance of subsidy programs and feed-in-tariff rates in influencing the adoption of solar pumps. This chapter also studies comparative valuation for receiving income from the sale of excess electricity in cash or as an offset in residential electricity bills and whether the type of transfer influences the uptake of solar irrigation pumps. Farmers' preferences for investing in solar water pump at the individual farm or accepting centralized solar feeder catering to many farms are also studied.

5.4: Discrete choice experiment approach

5.4.1: Context of valuation of the proposed objectives and attributes

Data from discrete choice experiments can be exploited for demand estimation and analysis, identifying consumer segments characterized by similar tastes and informing the design of products and services to match consumer preferences (Akcura and Weeks, 2014). The empirical analysis in this paper is based on original data from a stated choice experiment conducted with 859 farmers in the Indian State of Punjab in 2021-22 to elicit consumer valuations for attributes of grid-connected solar pumps. Grid-connected solar pumps are new to most farmers in Punjab, therefore the number of attributes in this discrete choice experiment was restricted to factors that are most likely to determine the substitution of electric pumps with solar pumps. Agarwal and Jain (2016) identified input costs, expected revenue from cultivation, and the cost of alternative irrigation solutions as the determinants of the economic sustainability of solar-powered irrigation. This study is carried out to examine the effect of financial incentives on improving the affordability of grid-connected solar pumps in Punjab agriculture.

A pilot survey was conducted by the author in December 2019 with 50 farmers of different districts in Punjab to identify the relevant attributes and levels for the discrete choice experiment. Farmers were asked to rank problems with the current regime of free electricity supply and opinions about changing the energy mix. Respondents were specifically asked for their feedback about the existing supply schedules and improving the design of future schemes. Secondly, extensive discussions were held with officials dealing with renewable energy policies in different State governments. Discussions revolved around the pros and cons of the existing schemes and suggestions for improving the affordability and acceptability of solar pumps. The full spectrum of issues from economic cost to the technical feasibility of solar pumps was discussed. Thirdly, experts in the electricity sector were interviewed to seek their opinion on the proposed attributes and levels. A thorough analysis of the results and the feedback gained during these discussions led to the selection of the final attributes and levels for this experiment.

Two attributes were chosen based on a literature review and interviews conducted in a pilot study: (1) the level of subsidy on the capital cost of a grid-connected solar pump and the type of income transfer from the sale of surplus solar energy, and (2) the buyback rate for selling surplus solar energy to the grid.

5.4.2: Description of attributes and levels

The Indian government gives a tremendous push for off-grid and grid-connected solar pumps by offering capital subsidies for individual solar pumps since 2014. Under the government scheme introduced in 2019, individual grid-connected agriculture pumps could be solarized with 30 percent subsidy provided by the central government and state government each and the remaining 40 percent contribution by the farmer. A more recent scheme introduced in 2020 provides 30 percent central financial assistance to developers for feeder-level solarization, replacing the capital subsidy on individual grid-connected solar pump schemes. A solar power plant with a capacity that can cater to the requirement of annual power for an agriculture feeder is installed by a developer selected by the state government. The farmer does not invest anything and does not earn additional income from the sale of surplus energy to the grid.

This experiment presented respondents with two alternatives - the choice of installing a subsidized grid-connected individual solar pump by availing the government subsidy scheme or drawing free solar energy from a solarized agriculture feeder installed by a developer at the distribution substation. Level one is the base level relating to solar agriculture feeder. It indicates the option of drawing free solar electricity from a solarized agriculture feeder without involving any investment by the farmer and giving no benefit of selling surplus solar power to the grid.

5.4.2.a: Subsidy on capital cost

The first attribute is the percentage of capital subsidy on the solar pump which has three levels. At level 1 the farmer does not pay anything as the cost of solarizing the agriculture feeder is borne by the developer. Level 2 offered sixty percent capital subsidy on the solar pump of either 7.5 HP or 10 HP capacity reflecting the government scheme. While the Punjab government offered sixty percent capital subsidy on the cost of solar pumps, other state governments offer higher capital subsidies. For instance, the Haryana government offered 75 percent capital subsidy and the Maharashtra government offered 80 percent capital subsidy on a solar pump. Maharashtra also offered 95 percent subsidy on off-grid solar pumps. Under a popular scheme of the Gujarat government, the farmer had to pay only 5 percent of the capital cost, and the remaining cost was financed through state subsidy and loan, interest on which was paid by the state government.

It was proposed to offer an enhanced subsidy of seventy-five percent of the pump cost to understand the preferences of the farmers in Punjab. The enhanced subsidy offer was in line with what other State governments were offering to encourage solar pump deployment. A higher subsidy component was expected to significantly improve the affordability of the solar pump. Level 3 offered an enhanced level of seventy-five percent subsidy on the cost of the grid-connected solar pump to the farmer. Further, as the government would save subsidy of $625 per consumer by replacing an electric pump with a solar pump, therefore more liberal financial assistance was proposed to be presented to the farmer.

The study has relied upon the estimates prepared by the Punjab Energy Development Agency for calculating the capital cost and the subsidized price of a solar pump (Punjab State Electricity Regulatory Commission, 2020). 7.5 HP and 10 HP solar pumps were considered for the experiment. Punjab Energy Development Agency has estimated the cost of 7.5 HP with 10 KW solar photovoltaic array as Rs. 410000 ($5148). As PEDA does not offer subsidy on 10 HP solar pump, hence the base cost of 7.5 HP pump was extrapolated to arrive at the estimated cost of Rs. 530000 ($6654) of 10 HP pump with 12.5 KW solar photovoltaic array. After giving a subsidy of seventy-five percent, the cost of a 7.5 HP pump with 10 KW solar panel was Rs. 102500 ($1287) and that of 10 HP pump with 12.5 KW solar panel was 132500 ($1663) to the farmer. Likewise, the subsidized cost of 7.5 HP pump with sixty percent subsidy was Rs. 164000 ($2059) and that of 10 HP pump was Rs. 212000 ($2661).

In addition to the subsidy, the attribute offered the choice of receiving income transfer from surplus solar energy in cash or as an offset in the farmer's residential electricity bill. This aspect has been elaborated in Section 5.3. Buy-back policies allow the banking of surplus solar energy in energy or monetary terms. Traditionally, guaranteed buyback of surplus solar energy policy has given additional cash income to the 'prosumer'. The credit from surplus solar electricity could also be traded off for a reduction in the residential electricity bill. This novel approach draws from the experience of the solar rooftop policy which allows an offset of surplus solar energy generated with electricity consumed from the grid. The pilot survey found that agriculture consumers in Punjab get subsidized farm power but pay very high electricity tariffs for domestic consumption. The economic benefit of getting relief on the residential electricity bill from the sale of surplus solar energy generated by grid-connected solar pumps was chosen to test the feasibility of this tool in influencing adoption and water pumping decisions. The option of adjusting the surplus solar energy income as an offset in the residential electricity bill might help to overcome the financing barrier to adoption and also discourage the over-pumping of groundwater.

5.4.2.b: Buyback rate

Grid-connected solar pumps come with the benefit of the buyback of surplus solar energy. It is estimated that an average farmer would be left with excess solar energy for sale after meeting his irrigation requirements (Punjab State Electricity Regulatory Commission, Petition 7 of 2020). Assuming a capacity utilization factor of 17.4 percent, the generation of surplus solar energy was estimated to be 15025 kWh from 7.5 HP motor with 10 KW solar array. According to PSPSCL's estimates, the self-consumption of farmers for their irrigation is 7000 kWh. The balance units of solar energy after self-consumption would be available for export to the grid. This study assumes that solar pumps export surplus solar energy to the grid after meeting self-consumption requirements. This setup increases the opportunity cost of electricity for the farmer. Two levels of buyback rate for the sale of surplus solar energy to the grid were presented to examine the effect of the buyback rate on farmers' decision-making.

Level 1 was the base level without any benefit from the buyback of surplus solar energy. Level 2 presented farmers with the option of selling the surplus solar energy @ Rs. 2.6 /kWh ($0.032), which is the levelized feed-in-tariff rate notified by the Punjab Government. Level 3 offered a higher buyback rate of Rs. 3.65/kWh ($0.045) for surplus solar energy. The justification for offering a higher buyback rate was drawn from the experience of higher rates offered by other state governments. Rajasthan Electricity Regulatory Commission has notified Rs. 3.44 per kWh as the rate for the purchase of excess solar energy by the distribution utility from grid-connected solar pumps (Rajasthan Electricity Regulatory Commission 2020). Gujarat's Suryashakti Kisan Yojana was launched with the feed-in-tariff rate of Rs. 7 per kWh, out of which Rs. 3.50/kWh was paid by the distribution utility and Rs. 3.50/kWh by the state government.

5.4.3: Experimental design

The respondents were asked to choose between an individual grid-connected solar irrigation pump or a solarized agriculture feeder set up by a developer. The attribute levels for the solar feeder were set to the base level. The attributes are summarized in Figure 5.1 and explained in more detail in the paras below. Figure 5.2 illustrates a choice card presented to the respondent. A questionnaire accompanying the choice sets included further questions on socio-economic characteristics, demographics, and opinions about the prevailing subsidy regime and satisfaction level with the current supply schedules and quality of power.

The experiment has two attributes, one with three levels and the second with five levels, hence there could be 5x3 = 15 choice profiles. The discrete choice sets were constructed using Ngene software. The experimental design consisted of a Ngene-fractional factorial design of eight choice sets. The design resulted in an efficiency of D-error = 0.8. In each choice set, the second alternative was the option of solarized agriculture feeder, hence it remained constant across all choice sets. All farmers were presented with all the choice sets. Each farmer had to make 16 decisions. This generated 13744 observations from in-person interviews with 859 respondents.

Figure 5:1 Attributes and Levels

Attributes	**Levels**
1. Subsidy on capital cost of solar PV with income transfer	No subsidy
	60 percent with cash income
	60 percent with offset in residential bill
	75 percent with cash income
	75 percent with offset in residential bill
2. Buy back rate	No buy back rate
	Rs. 2.60/kWh
	Rs. 3.60/kWh

Figure 5:2 Example Choice set

Attribute	**Alternative 1**	**Alternative 2**
	Individual grid connected agriculture solar pump	**Feeder level solarization**
What would you choose? (Please choose one of these options)		
Subsidy on solar pump and income transfer	Seventy five percent subsidy with cash income 75% subsidy on solar pump + Cash income from buyback	No subsidy, no income
Buyback rate	Rs. 2.60/kWh for sale of surplus solar energy	No buy back rate
Preferred choice (tick)	☐	☐

5.4.5: Model Specification

The analysis of the choices made in a discrete choice experiment is based on random utility theory, developed by Mcfadden (1974). Specifically, it assumes that a decision maker, labeled n, facing a choice among J alternatives obtains a certain level of utility (or profit) from each alternative. The utility that decision maker n obtains from alternative j is U_{ni} *, j = 1, …..J.* Decision maker will choose i if

$$U_{ni} > U_{nj} \forall j \neq i \quad (5.1)$$

This utility is known to the decision maker but not to others. Since there are unobservable aspects of utility, $V_{nj} \neq U_{nj}$, Utility is decomposed as $U_{nj} = V_{nj} + \varepsilon_{nj}$, where ε_{nj} captures the factors that affect utility but are not included in V_{nj}.

The probability that n chooses alternative i is

$$P_{ni} = Prob(U_{ni} > U_{nj})\ \forall j \neq i$$
$$= Prob(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj})\ \forall j \neq i$$
$$= Prob(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj})\ \forall j \neq i \quad (5.2)$$

This probability is a cumulative distribution, namely that probability of each random term $\varepsilon_{nj} - \varepsilon_{ni}$ is below the observed quantity $V_{ni} - V_{nj}$. Using the density $f(\varepsilon_n)$, the cumulative probability can be re-written as

$$P_{ni} = Prob(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}) \forall j \neq i$$
$$= \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \forall j \neq i)\ f(\varepsilon_n)\ d\epsilon_n \quad (5.3)$$

where $I(.)$ is the indicator function, equaling 1, when the expression in parentheses is true and 0 otherwise. This is a multidimensional integral over the density of the unobserved portion of utility, $f(\varepsilon_n)$. Different discrete choice models are obtained from different specifications of this density, i.e., different assumptions about the distribution of the unobserved portion of utility. The logit is derived under the assumption that the unobserved portion of utility is distributed *iid* extreme value (Train 2009). Traditionally the choice is modeled using conditional logit in which choice is independent of irrelevant alternatives or error terms are assumed to be independently and identically distributed according to Gumbel distribution (Siyaranamual et al., 2020). This study applied conditional logit model and mixed logit model, which has a more flexible formulation.

The logit family of models is recognized as the essential toolkit for studying discrete choices (Hensher and Greene 2003). But there are practical problems with logit models. Logit can represent systematic taste variation which relates to observed characteristics of decision maker, but does not account for random taste variation, or differences in tastes that cannot be linked to observed characteristics. Secondly, the logit model exhibits equal proportional substitution across alternatives. This is due to the assumption of independence from irrelevant alternatives or IIA. This implies that for any two alternatives *i* and *k*, the ratio of the logit probabilities does not depend on any alternatives other than *i* and *k*. IIA property has some practical uses as it allows examining choices among a subset of alternatives and not among all alternatives. If the researcher believes that the IIA property holds adequately well, then a model with the relevant alternatives could be estimated by excluding sampled individuals who used other alternatives from the analysis. This strategy would save the researcher considerable time and expense developing data on other alternatives, without hampering ability to examine factors related to the relevant alternatives. Thirdly, logit model can capture dynamics of repeated choice when unobserved factors are independent over time in repeated choice situations, but it cannot handle situations where unobserved factors are correlated over time (Train 2009). Therefore, to allow for general patterns of substitution, more flexible models are needed.

Mixed logit model is considered a highly flexible model that can approximate any random utility model (McFadden and Train, 2000). It obviates the three limitations of standard logit by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time. Mixed logit models, also called random-parameters or error-components logit, are a generalization of standard logit that do not exhibit the restrictive "independence from irrelevant alternatives" property and explicitly account for correlations in unobserved utility over repeated choices by each customer (Revelt and Train 1998). Unlike probit, it is not restricted to normal distributions. Its derivation is straightforward, and simulation of its choice probabilities is computationally simple (Train 2009).

The derivation of mixed logit probability is based on random coefficients. The decision maker faces a choice among J alternatives. The utility of person n from alternative j is specified as

$$U_{nj} = \beta_n' x_{nj} + \varepsilon_{nj} \tag{5.4}$$

where x_{nj} are observed variables that relate to the alternative and decision maker, β_n is a vector of coefficients of these variables for person *n* representing his tastes and ε_{nj} is a random term that is independent and identically distributed of extreme value. The coefficients vary over decision makers in the population with density $f(\beta)$. This density is a function of parameters θ that represent, for example, the mean and covariance of the β's in the population. This specification is the same as for standard logit except that β varies over decision makers rather than being fixed.

The usual form of the mixed logit probability is:

$$P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}}\right) f(\beta) d\beta \quad (5.5)$$

The mixed logit probability is a weighted average of the logit formula evaluated at different values of β, with the weights given by the density *f(β)*. The researcher specifies a distribution for the coefficients and estimates the parameters of the distribution. By specifying the explanatory variables and density appropriately, the researcher can represent any utility maximizing behavior by a mixed logit model. In most applications, such as Revelt and Train (1998) and Bolduc and Ben Akiva (1996), *f(β)* is specified to be normal or lognormal: β ~ N(b, W) or ln β ~ N(b, W) with parameters b and W which are estimated (Train 2009).

Mixed logit model allows attribute coefficients to vary across respondents, accounting for preference heterogeneity and improving the realism of model assumptions. Secondly, mixed logit models adjust the standard errors of utility estimates to account for repeated choices by the same individual.

5.4.6: Estimation strategy

The farmers were faced with two alternatives in the experiment. The first alternative was to invest in individual grid-connected solar agriculture pump installed at farm and get the benefit of buyback of surplus solar energy. The second alternative was to receive free solar electricity from a solarized agriculture feeder set up by a private developer and not get the benefit of additional income from the sale of surplus solar energy. The deterministic part of the utility function is

$$Adoption_{SIP} = \beta_0 + \beta_1 \; x \; SixtyCas_1 + \beta_2 \, x \, SixtyReb_2 + \beta_3 x \, SeventyCas_3 + \beta_4 \, x \, SeventyReb_4 + \beta_5 \, x \; Buybackrate_1 + \varepsilon \tag{5.6}$$

The four attribute levels of capital subsidy with the type of income transfer for alternative 1 were modelled as dummy variables – *$SixtyCas_1$, $SixtyReb_2$, $SeventyCas_3$ and $SeventyReb_4$*. Preferences were modeled relative to a base case (coded as 0) for dummy variables. where sixty percent subsidy on solar pump with buyback income earned in cash is denoted by $SixtyCas_1$ and β_1 is the associated sensitivity parameter; sixty percent subsidy on solar pump with buyback income earned as offset in residential electricity bill is denoted by $SixtyReb_2$ and the associated sensitivity parameter is β_2; seventy-five percent on solar pump with buyback income earned in cash is denoted by $SeventyCas_3$ and the associated sensitivity parameter is β_3; seventy-five percent subsidy on solar pump with buyback income earned as offset in residential electricity bill is denoted by $SeventyReb_4$ and the associated sensitivity parameter is β_4; the buyback rate for purchase of surplus solar energy is denoted by *Buyback*rate$_1$ and the associated sensitivity parameter is β_5. β_0 is a constant reflecting farmers' preference for solar pump.

The estimated parameters were interpreted as the marginal value of a movement from the base case to a defined level. The parameter for '$SixtyReb_2$' shows the value of moving from sixty percent capital subsidy with cash income to sixty percent capital subsidy with offset in residential bill. Similarly, '$SeventyCas_3$' shows the value of moving to seventy-five percent capital subsidy with cash income, and '$SeventyReb_4$' shows the value of moving to seventy-five percent capital subsidy with offset in residential bill. Buyback rate is treated as a continuous variable in the estimation. Feeder-level solarization corresponding to no capital subsidy on solar pump is given dummy value of 1 for second alternative and 0 otherwise.

The mixed logit model was fitted on the choice data treating the coefficient for the rate as fixed and the subsidy with income transfer coefficients as normally distributed. A main effects model was used without any interaction effects. Each farmer was presented with eight choice sets and there were two alternatives in each choice set – the first alternative for individual solar pump and the second alternative for feeder-level solarization. The survey produced 13744 observations in total.

5.5: Empirical results

i) Figure 5.3 presents the main results and sheds light on the average valuation of the various attributes in the population. The choice was modelled using mixed logit or random parameters logit, random effects probit and conditional logit models. More specifically, the IIA assumption was relaxed by using mixed logit and random effects probit. All estimated parameters are highly significant and in the expected direction in the three models. Results of mixed logit and conditional logit are presented in figure 5.3 below. The coefficients and WTP values with random effects probit model are reported in figure 5.14 in the Appendix. Farmers have strong preferences for seventy-five percent subsidy on the cost of agriculture solar pump as compared to sixty percent subsidy. While the higher subsidy is important to all farmers, there is significant increase in utility for higher component of subsidy with option of cash payment of income from sale of surplus solar energy. The positive value of the coefficient for buyback rate indicates preference for installing individual grid connected agriculture solar pump with buyback option than drawing solar energy from feeder-level solarization. There is evidence of preference for cash income from sale of surplus energy as compared to receiving an offset in the residential electricity bill.

Figure 5:3 Estimation Results

Attribute	Coefficient	Std. Error	Coefficient	Std. Error
	Mixed logit		Conditional logit	
Mean				
Sixty_Reb	-2.3148***	0.199	-1.7529***	0.093
Seventy_Cas	3.4559***	0.250	2.9486***	0.103
Seventy_Reb	0.1571***	0.079	0.1868***	0.070
Buy back rate	0.8953***	0.065	0.8208***	0.061
const	-3.2122***	0.212	-2.9777***	0.200
Log likelihood	*-3284.60*		*-.3304.36*	
Pseudo R^2	*0.3070*		*0.3063*	
N	*13744*		*13744*	
SD				
Sixty_Reb	1.2992***	0.227		
Seventy_Cas	1.1648***	0.294		
Seventy_Reb	0.8556***	0.141		
AIC	6585.217		6618.721	
BIC	6645.443		6656.363	

****p < .05*

On an average, higher buy back rate, higher capital subsidy of seventy-five percent on the cost of a grid connected solar irrigation pump and cash transfer of buyback income is likely to increase the probability of choosing individual agriculture solar pump. Further, there was significant preference heterogeneity for the attributes.

Proportion of population with positive effect: Assuming a normal distribution for random parameters, mixed logit model provides output that can be used to calculate the proportion of respondents for whom an incentive attribute has a positive or negative effect on preferences. From the magnitude of the standard deviations relative to the mean coefficients, 3.6 percent prefer sixty percent subsidy with offset in residential electricity bill, 0.15 percent farmers were not likely to prefer seventy-five percent subsidy with cash payment and 42 percent farmers were not likely to prefer seventy-five percent subsidy with offset in residential electricity bill. These figures are given by $100\ x\ \Phi(b_k/s_k)$, where Φ is the cumulative standard normal distribution and b_k and s_k are the mean and standard deviation, respectively of the *kth* coefficient (Hole 2007).

ii) Odd Ratios: The logit model provides an estimate of the increase in the log-odds of the choice for a given alternative. The exponential function of the log odds is the Odds ratio. They are useful for substantive interpretation of the model and indicate the odds times increase or decrease associated with the explanatory variable compared to the reference level. The Odds Ratio are presented in figure 5.4 below.

Figure 5:4 : Odds Ratios

Attribute	Odds Ratio	Std. Error
Sixty_Reb	0.173***	0.016
Seventy_Cas	19.080***	1.975
Seventy_Reb	1.205***	0.085
Buy back rate	2.272***	0.139

*******p < .05*

The subsidy component of seventy-five percent has 19 times higher odds ratio of being chosen as compared to the base level. Similarly, the buyback rate has 2 times higher odds ratio as compared to base level.

iii). Willingness to pay/willingness to accept: Willingness to pay/willingness to accept for an attribute is the ratio between the attribute's coefficient and the price coefficient, which is estimated as

$$Willingness\ to\ pay = \frac{\beta_{attribute}}{\beta_{rate}}$$

Willingness to pay/willingness to accept estimates and 95% confidence intervals are presented in figure 5.5 below. WTP/WTA values from mixed logit are estimated within preference space. The results indicate that WTP/WTA is Rs. 3.8($0.04)/kWh for seventy-five percent subsidy with cash income and Rs. 0.17($0.002)/kWh for seventy-five percent subsidy with offset in residential bill. On the other hand, the farmer may need to be compensated for accepting reduced subsidy of sixty percent. The WTP/WTA values estimated with random effects probit model are reported in figure 5.14 in the Appendix.

Figure 5:5 Willingness to pay/willingness to accept

Attribute	WTP	Std. Err.	WTP	Std. Err.
	Mixed logit		Conditional logit	
Sixty_Reb	-2.585***	0.278	-2.135***	0.189
Seventy_Cas	3.859***	0.377	3.592***	0.282
Seventy_Reb	0.1755***	0.089	0.227***	0.087

****p < 0.0*

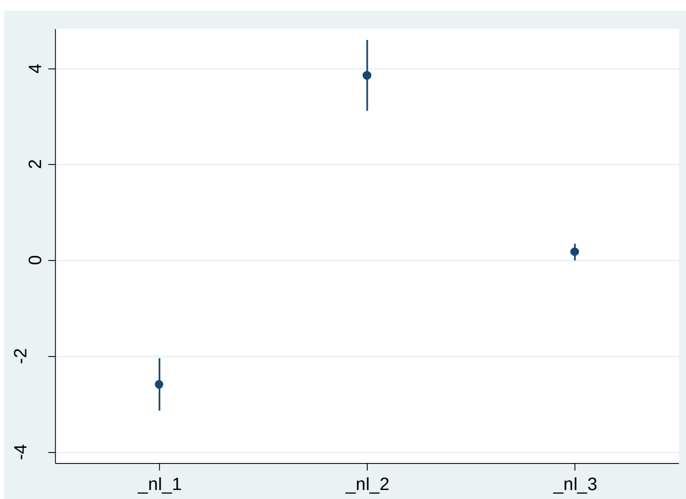


Figure 5:6 Willingness to pay estimates and 95% confidence intervals

There is some debate regarding the appropriateness of calculating WTP estimates in preference space. Of particular concern is the assumption regarding the distribution of the price variable. A fixed price coefficient assumed to estimate the distribution of consumers' willingness to pay for the attributes, implies that the standard deviation of unobserved utility or scale parameter is the same for all observations. In some situations, ignoring the variation in estimation can lead to erroneous interpretation. Train and Weeks (2005) suggest a way to circumvent this problem by estimating the mixed logit model in WTP space rather than in preference space (Hole 2016). The estimation of the mixed logit model in WTP space is presented in figure 5.17 in the Appendix. While alternative techniques have been suggested, however no gold standard has been accepted so far (Ryan et al., 2012). The models in preference space continue to be considered to fit the data better.

iv) Predicted probabilities: The discrete choice experiment results have been used to show how the probability changes for an alternative, in other words, how the probabilities vary in response to changes in the levels of attributes (Hole 2007). Figure 5.7 shows the probability of choosing solar agriculture pump changes with the subsidy percentage under mixed logit model. The results of predicted probabilities from conditional logit and random effects probit models are presented in figure 5.16 in the Appendix.

Figure 5:7 Predicted probabilities

Attribute	Mean	Std. Dev
	Mixed logit	
Sixty_Reb	-0.288***	0.11
Seventy_Cas	0.425***	0.15
Seventy_Reb	0.025***	0.02

*******p < .05*

Potential uptake of choosing solar pump is simulated by comparing the uptake of solar agriculture pump with seventy-five percent subsidy with respect to the baseline level of sixty percent subsidy with offset in residential bill. The results of the selected simulations are shown in figure 5.8. There is higher probability of uptake for capital subsidy with cash payment of buyback income option.

Figure 5:8 : Change in probability

Attribute	Mean	Std. Err.	Mean	Std. Err.
	Mixed logit		Conditional logit	
Seventy_Cas	0.993***	0.001	0.982***	0.002
Seventy_Reb	0.844***	0.029	0.748***	0.020

****p < .05*

Figure 5.15 in the Appendix reports the marginal effects computed at means with random effects probit and conditional logit models. Marginal effects represent the variation in choice with a change in the level of the capital subsidy and buyback option.

v) Comparison of coefficients between the regions: There are considerable spatial differences in the strength of farmers preferences for various attributes of solar pumps, as illustrated in Figure 5.9. Farmers in the Malwa, Majha and Doaba regions are statistically more likely to support seventy-five percent capital subsidy on solar irrigation pumps with cash payment of buyback income. Doaba region farmers are the most inclined to adopt solar irrigation pumps. Farmers in the three regions prefer the attribute of buyback rate, although Majha region farmers are more likely to choose irrigation pumps with the option of buyback of surplus solar energy. Majha region farmers do not show any preference for the option of offset in residential electricity bill. This finding implies that farmers' preferences across agro-ecological regions cannot be pooled together. However, it can be inferred that farmers across all regions are equally interested in solar pumps as an alternative to subsidized electric pumps.

Figure 5:9 Estimation results – region-wise

Attribute	Malwa	Majha	Doaba
Sixty_Reb			
Mixed logit	-1.932***	-3.435***	-2.761***
	(0.219)	(0.620)	(0.924)
Conditional logit	-1.615***	-2.111***	-1.992***
	(0.11)	(0.205)	(0.291)
Seventy_Cas			
Mixed logit	3.281***	3.847***	4.690***
	(0.256)	(0.723)	(0.818)
Conditional logit	2.829***	3.512***	3.149***
	(0.123)	(0.316)	(0.259)
Seventy_Reb			
Mixed logit	0.235***	-.3625***	0.498***
	(0.108	(0.159)	(0.189)
Conditional logit	0.285***	-0.357	0.5059***
	(0.088)	(0.157)	(0.184)
Buy back rate			
Mixed logit	0.916***	1.057***	0.680***
	(0.082)	(0.146)	(0.170)
Conditional logit	0.815***	1.002***	0.6354***
	(0.075)	(0.141)	(0.163)
N	8912	2752	2080

****p < .05*

vi) Interaction terms: An approach followed in this study was to search for possible association between the choices made by farmers and their socio-economic and demographic characteristics. The heterogeneity in preferences by education level, land size, tube well ownership and load capacity of farmers is estimated using conditional logit and random effects probit models. The results are presented in Figure 5.13 in the Appendix. Results show that education is an important explanatory variable. Matriculate and graduate farmers are significantly more likely to agree for buyback of surplus solar power. There is no preference for the offset option among matriculates and graduates.

Land ownership has an influence on preferences. Semi-medium, medium, and large farmers are significantly more likely to prefer buyback of surplus solar power. Similarly multiple tube well owners significantly prefer buyback of surplus solar power, with increases in tube well ownership resulting in more favorable inclinations. Small and marginal farmers show positive preferences for buyback option, although the coefficients are not significant. Again, there is no preference for offset option; negative preferences are significant for small farmers, large farmers, single tube well owners and multiple tube well owners. Larger farmers are relatively more likely to adopt solar irrigation pumps with higher capital subsidy, although the coefficients are not significant. However, semi-medium farmers do not significantly prefer capital subsidy on solar pump.

Farmers with pumps of different capacities have significant and positive preferences for buyback of surplus solar power. Similarly, they have significantly negative preferences for seventy-five percent subsidy with offset option. Again, farmers with medium and high load do not significantly prefer sixty percent capital subsidy with offset option. Farmers with low load are significantly not likely to prefer seventy-five percent subsidy with cash income, in contrast to farmers with high load, although the positive coefficient for high load farmers is not significant.

5.6: Discussion

Given that grid-connected solar pumps can reduce the intense dependence on fossil fuels, increase the integration of solar solutions, and preserve the aquifer, besides giving farmers additional benefits through net-metering scenarios and annual energy surpluses (Rubio-Aliaga et al., 2019), this study is an attempt to understand farmers' preferences for them. The main research question addressed is whether the installation rate of these pumps is affected by the capital subsidy and buyback rate. The analysis is based on a choice experiment conducted with 859 farmers in Punjab in 2021-22. The results from this study align with most solar energy literature and emphasize high upfront costs and uncertainty in financial returns as barriers to solar pump adoption in agriculture.

The econometric analysis suggests that a higher subsidy on the capital cost of a solar pump is a highly significant predictor of individual agriculture solar pump adoption. The results show that a seventy-five percent capital subsidy is acceptable to 91 percent of the farmers at the buyback rate of Rs. 2.6/kWh. Farmers are discouraged by sixty percent subsidy, as it is preferred by only 35 percent. The option to draw buyback income as an offset in the residential bill is preferred by 25 percent at the lower buyback rate and 62 percent at the higher buyback rate with a seventy-five percent capital subsidy. The preference for the offset option is considerably lower at 7 percent and 13 percent at sixty percent subsidy for the two buyback rates.

Moreover, as expected, there are significant differences in the WTP/WTA for different attribute levels. Farmers are willing to pay more for the improved level of capital subsidy than the subsidy offered under the government scheme. On the other hand, farmers are willing to pay less for the relatively lower capital subsidy and would need to be compensated to install solar agriculture pumps. This study also delivers empirical evidence showing that the buyback rate drives adoption behavior. The effect of the buyback rate is positive and significant across the population. If subsidy levels fall below expectations, feeder-level solarization is preferred.

The spatial picture confirms evidence of the positive effect of higher capital subsidy and buyback options on installation preferences. The effect of contextual factors is considered on adoption behavior and the report suggests that educated farmers are more likely to adopt solar agriculture pumps. Farmers with medium, and large landholdings and multiple tube wells prefer the buyback option. The results can be exploited for the targeted delivery of solar agriculture pumps in Punjab.

The feed-in tariff can be the main instrument to promote the adoption of decentralized solar generation in agriculture and prevent over-exploitation of groundwater. Introducing a buyback rate differentiated by season and location is suggested as an affordable way to promote groundwater conservation. Pegging the buyback rate at the correct price would depend on the marginal profitability of water use. A very low buyback rate would disincentivize farmers from changing pumping behavior while a very high buyback rate is likely to create perverse incentives (Franklin 2015). Applying targeted interventions informed by the preferences and consent of the farmers could bring about the desired change.

Another component of the analysis is the possibility of a nonlinear relationship between solar uptake and income; as income increases, it is possible that solar pump uptake might not increase following a straight-line relationship, it could be curved. Higher-income farmers or those with higher accumulated assets may have reduced motivation for investment in the solar pump due to lower stress of additional expenditure on diesel. Secondly, the positive relationship between solar uptake and income may be restricted to the low end of the income distribution. After a peak in the middle of the income distribution, a negative relationship between income and solar panel uptake is possible for high-income households. More affluent farmers may be less worried about high diesel prices (Best and Chareunsy, 2022).

This study contributes to the existing literature in presenting the results of the first-choice modeling on the adoption of solar PV technology in agriculture in Punjab. From the perspective of the government to the extent solar pumps wean farmers away from electric pumps, there would be a reduced burden of electricity subsidies and greenhouse emissions. While a thorough examination of the social welfare consequences of agriculture solar pump is beyond the scope of this study, however, rough estimates of the cost of incentivizing uptake of agriculture solar pumps through a higher subsidy program financed out of electricity subsidy savings are calculated in Figure 5.10 below. The analysis is carried out for 7.5 HP pump.

Figure 5:10 Financing higher solar pump subsidies out of electricity subsidy savings

	For the Farmer		
1	Capital cost of 7.5 HP 10 KW solar pump	$	5166.07
2	Punjab government's contribution - 45% of cost	$	2324.73
3	Farmers contribution - 25% of cost	$	1291.51
4	Total generation	kWh	15025
5	Self-consumption	kWh	7000
6	Surplus generation	kWh	8025
7	Buyback rate for surplus energy	$/kWh	0.032
8	Agriculture tariff on electric pumps	$/kWh	0.071
9	Local purchase of solar energy by utility	$/kWh	0.012
10	Gain for the farmers from surplus generation {2.6*8025}	$	261.99
11	Additional gain due to efficient pump (20% saving in energy consumption) - {20% of 7000}	kWh	1400
12	Additional income for farmers due to efficient pump {2.6*1400}	$	45.70
	Total gain for farmers {10+12}	$	307.69
	For the Utility		
13	Utility saving in electricity subsidy {5.66*7000}	$	497.48
14	Additional gain from surplus energy purchased locally @ Rs. 1/kWh {1*8025}	$	100.76
15	Additional gain from surplus power purchased due to efficient motor {1*1400}	$	17.57
	Cumulative gain for utility {13+14+15}	$	615.83
	For the Govt		
16	Additional burden of giving 75% subsidy	$	772.22
	For the environment		
17	Total solar generation	MWh	15.025
18	Weighted average carbon emission factor	t/MWh	0.82
19	Reduced carbon dioxide emissions	t/MWh	12.3205

($-Rs.79.6) *Authors calculations based on Tariff order, Punjab State Electricity Regulatory Commission (2020)*

The above analysis performed for one farmer shows that there is a clear social benefit from substituting electric pumps with solar pumps in agriculture. There would be a net gain of $616 for the utility and additional income to the farmer would be $308 for 10 KW solar pump installed at the farm. The farmer would get daytime reliable solar power for irrigation according to his requirement. The government has set a target of solarizing 25000 pumps in 2021-22. Determining the net cost or benefit to the economy of substituting 25000 grid-connected solar pumps with electric pumps in Punjab, we find that the additional cost of subsidizing solar pumps would be $42.5 million to the government and the net benefit of reduced carbon emissions would be 308000 ton/MWh. On the other hand, setting up solar feeders involves huge investment costs, expenditure on operation, management, maintenance, and gestation period. It is estimated that the cost of setting up a 1MW solar plant in India is $0.608 million, which on average can cater to 133 irrigation pumps of 10 KW capacity each. The government has targeted the setting up of 54 MW capacity solar feeders for supplying solar energy to 25000 grid-connected pumps. The approximate cost of investment would be around $32.8 million. If the utility additionally incentivizes farmers for consuming power less than benchmark consumption under feeder-level solarization, this would entail additional expenditure. The farmer would remain dependent on the grid for meeting irrigation needs. From the convenience perspective, individual solar pumps are likely to be more convenient.

Further, subsidizing the initial cost of the solar photovoltaic pump is much cheaper on a life cycle cost basis when compared with diesel-powered pumps. The fuel and replacement cost for solar pumps is negligible and this reduces the life cycle cost (Dadhich and Shrivastava 2017). Solar pumps can serve as an economically more attractive option for farmers using diesel pumps who are awaiting the release of new electric connections in Punjab. Figure 5.11 shows the lower life cycle cost of the solar pump as compared to the diesel pump. Studies show that solar pump has the potential to replace conventional diesel or electric pump due to their advantages in improving energy efficiency (Sreewirote et al., 2017).

Figure 5:11 Life Cycle Cost Analysis comparison of solar and diesel pump

Cost	7.5 HP Solar PV	5 HP Diesel engine
Capital cost ($)	5148.1	376.6
Maintenance cost ($)	852.2	941.7
Fuel cost ($)*	-	41430.9
Replacement cost ($)	-	376.6
Total outflows ($)	6000.4	43126.1
Present value of outflow ($)	5454.9	39205.5
Salvage value ($)	617.7	75.3
Present value of inflow ($)	561.6	68.4
Life cycle Cost ($)	4893.3	39137.05

Authors calculations based on Dadhich & Shrivastava (2017)
**Annual fuel cost of diesel pump: Specific fuel consumption x capacity x Fuel price x 6 hours x 150 days, Rs. 79.64=$, at 2020 prices*

The Net Present Value and Benefit Cost Ratio is estimated at 10 percent discount rate to illustrate the economic viability of adopting individual grid-connected solar pumps. The project analysis is done for 25 years. The project cost is the sum of the capital cost and the maintenance cost of the pump. The outflow is the purchase cost of surplus solar energy. The cash inflow is the electricity subsidy savings and benefit of local purchase of solar energy. The discounted benefits exceed the present value of the costs and the investment. The government could provide higher capital subsidies to effectively promote the adoption of solar agriculture pumps.

Figure 5:12 Net Present Value and Benefit Cost Ratio

	Grid connected solar pump
Net Present Value of Inflows ($)	16676
Net Present Value of Outflows ($)	11409
Benefit Cost Ratio	1.46

The grid-connected solar pump can serve as a viable green alternative to electric pumps, provided a good financing model and institutional support are made available. Arguably, the deployment of solar pumps increases agricultural productivity and farmers' income (Beaton

2019), but the impact on water extraction can be weakened by using water more efficiently. The ability to reduce excessive groundwater region will vary with the region. They are a win-win solution where farmers already use surface water. Solar pumps are considered economically feasible for areas with adequate solar radiation, crops with low-water demand and high economic value, small plots, and irrigation techniques with higher efficiency (Noumon, 2008). Innovative policies for managing groundwater in a sustainable way include optimal sizing of the solar array, building inbuilt sensors, connecting solar adopters to the grid, promoting service model, and setting correct electricity prices to encourage greater substitutions in favor of solar (Gupta 2019).

5.7: Conclusions

Although Punjab has potential for solar energy generation, only a small proportion of the farmers use solar agriculture pumps. This study applied choice modeling to understand the acceptance of grid-connected solar pumps and farmers' willingness to pay for solar energy. Choice data was collected from 859 farmers in Punjab in 2021-22 and mixed logit and conditional logit models were used to estimate farmers' valuations for subsidy and buyback options.

Results show that the capital subsidy on the solar pump is positively associated with farmers' adoption intention. The probability of willingness to pay for solar pumps increases with higher capital subsidies. The seventy-five percent capital subsidy is associated with 93 percent uptake. The sixty percent subsidy has 35 percent acceptance rate. There are heterogeneous preferences for different types of financial incentives. The study establishes the need to support the capital cost of the solar pump with subsidies and easy access to credit, particularly credit-linked capital subsidy for installing solar pumps as most Punjab farmers lack financial resources.

The results demonstrate that the socioeconomic characteristics of the farmers play a significant role in the deployment of solar agriculture pumps. More educated, medium, and large farmers and multiple tube well owners are more likely to accept grid-connected solar pumps. The lower subsidy, lack of awareness, and lack of institutional support are the main reasons for the stated unwillingness to install the solar pump. Providing awareness about installing and using solar pumps is likely to enhance public acceptance of solar PV technology in agriculture.

The high preference for buyback of surplus solar energy among various socioeconomic groups and sub-regional divisions has strategic implications. We obtain three takeaways. First farmers do express, on average a preference for buyback, although policy measures designed to promote solar pump adoption by reducing the initial installation cost through higher subsidies are relatively preferred more to policy measures that reduce subsequent pump operating expenditure through attractive energy buyback programs. Secondly, the combination of subsidy and buyback drives farmers to choose individual pumps more often over solar feeders. Farmers, when deciding about installing solar pumps carefully weigh the subsidy support and feed-in-tariff induced returns against the risks involved in the investment. Grid-connected pumps with the facility of selling back excess solar energy are likely to promote greater acceptance among farmers. Feeder-level solarization is considered the second-best option. This can provide grid-like service to a considerable extent. However, factors like cost, grid reliability, etc. limit universal coverage. From the convenience perspective, individual pumps are more convenient. Thirdly, going deeper into our analysis, the energy buyback option can incentivize judicious water use.

These findings can help optimize the mix of individual solar pumps and solar feeders established by developers at different sites for incentivizing the prosumers in selling solar energy and consumers in managing their demand to promote balanced development. An increase in demand and technological advancements in solar energy will present opportunities for individual and community solar penetration. Future work could determine different incentives to be offered to prosumers and consumers and buyback prices differentiated by season and location.

Although the study adds to the understanding of farmers' preferences to install solar agriculture pumps and provides policy measures for deploying solar pumps, it has several limitations. As the study is based on stated preferences, there is the possibility of hypothetical bias. Moreover, it is important to note that the stated farmers' willingness to pay is not an actual payment for the solar pump. Future research can extend the experiment to explore locally appropriate service delivery models and other incentive instruments for solar energy penetration. In the free-riding context, a possible extension could be to study the effect of a tax to prevent over-extraction of groundwater and reward for reducing consumption. Future work could include supplementary questions designed to identify the confidence of the respondents about their choices and whether they would hypothetically purchase the pump chosen in the choice experiment. Studying the impact of adoption by an individual farmer on other farmers' adoption decisions can be extended in future research.

The results of this study provide essential information for developing effective solar energy promotion policies. Given the extent of network externalities in the electricity sector, it is crucial that the adoption process of solar pumps accelerates, and the government subsidizes solar technology. Promoting solar pumps will make them cost competitive with traditional sources of power generation and foster technological improvements, thereby making them economically self-sustainable in the long run. These findings are not only relevant for facilitating the adoption of solar pumps but can also effectively encourage the adoption of other renewable energies.

References

Agrawal, S., & Jain, A. (2016). Sustainability of solar-based irrigation in India: Key determinants, challenges and solutions. Working Paper, Council on Energy, Environment and Water, New Delhi, 1-34.

Akcura, E., & Weeks, M. (2014). Valuing reliability in the electricity market. In Faculty of Economics, University of Cambridge UK Working Paper.

Al-Saidi, M., & Lahham, N. (2019). Solar energy farming as a development innovation for vulnerable water basins. Development in Practice, 29(5), 619-634.

Babich, V., Lobel, R., & Yücel, Ş. (2020). Promoting solar panel investments: Feed-in-tariff vs. tax-rebate policies. Manufacturing & Service Operations Management, 22(6), 1148-1164.

Batley, S. L., Colbourne, D., Fleming, P. D., & Urwin, P. (2001). Citizen versus consumer: challenges in the UK green power market. Energy Policy, 29(6), 479-487.

Baweja, S., Aggarwal, R., Brar, M., & Lal, R. (2017). Groundwater depletion in Punjab, India. Encyclopedia of Soil Science, 2017, 1-5.

Beaton, C., Jain, P., Govindan, M., Garg, V., Murali, R., Roy, D., & Pallaske, G. (2019). Mapping Policy for Solar Irrigation Across the Water-Energy-Food (WEF) Nexus in India. International Institute for Sustainable Development.

Best, R., & Chareunsy, A. (2022). The impact of income on household solar panel uptake: Exploring diverse results using Australian data. Energy Economics, 112, 1-9.

Bolduc, M. B. A. D., & Ben-Akiwa, M. (1996). Multinomial probit with a logit kernel and a general parametric specification of the covariatice structure. Working Paper Massachusetts Institute of Technology: Cambridge Mass.

Borchers, A. M., Duke, J. M., & Parsons, G. R. (2007). Does willingness to pay for green energy differ by source?. Energy Policy, 35(6), 3327-3334.

Chand, Ramesh (1999). Emerging crisis in Punjab agriculture: Severity and options for future. Economic and Political Weekly, A2-A10.

Chapman, A. J., McLellan, B., & Tezuka, T. (2016). Residential solar PV policy: An analysis of impacts, successes and failures in the Australian case. Renewable Energy, 86, 1265-1279.

Cicia, G., Cembalo, L., Del Giudice, T., & Palladino, A. (2012). Fossil energy versus nuclear,wind, solar and agricultural biomass: Insights from an Italian national survey. Energy Policy, 42, 59-66.

Dadhich, G., & Shrivastava, V. (2017, August). Economic comparison of solar PV and diesel water pumping system. In 2017 International Conference on Information, Communication, Instrumentation and Control, 1-6.

Ek, K. (2005). Public and private attitudes towards "green" electricity: the case of Swedish wind power. Energy Policy, 33(13), 1677-1689.

Franklin, B. (2015, October). Solar irrigation pumps: can electricity buy-back curb groundwater over-use?. In International Commission on Irrigation and Drainage's 26th Euro-Mediterranean Regional Conference and Workshop on "Innovate to Improve Irrigation performances," Montpellier, France, 12-15.

Graber, S., Narayanan, T., Alfaro, J., & Palit, D. (2018). Solar microgrids in rural India: Consumers' willingness to pay for attributes of electricity. Energy for Sustainable Development, 42, 32-43.

Gupta, E. (2019). The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India. Energy Policy, *129*, 598-609.

Gupta (2020), 'The case for distributed solar with storage', PV Magazine December 2020 https://www.pv-magazine-india.com/2020/12/10/the-case-for-distributed-solar-with-storage.

Hensher, D. A., & Greene, W. H. (2003). The mixed logit model: the state of practice. Transportation, 30(2), 133-176.

Higgins, A., McNamara, C., & Foliente, G. (2014). Modelling future uptake of solar photo-voltaics and water heaters under different government incentives. Technological Forecasting and Social Change, 83, 142-155.

Hole, A. R. (2007). Fitting mixed logit models by using maximum simulated likelihood. The Stata Journal, 7(3), 388-401.

Hole, A. (2016). MIXLOGITWTP: Stata module to estimate mixed logit models in WTP space. Statistical Software Components. Boston College Department of Economics.

Husain, A. A., Phesal, M. H. A., Ab Kadir, M. Z. A., & Ungku Amirulddin, U. A. (2021). Techno-Economic Analysis of Commercial Size Grid-Connected Rooftop Solar PV Systems in Malaysia under the NEM 3.0 Scheme. Applied Sciences, 11(21), 10118.

ICID 2019, Solar Powered Irrigation Systems in India: Lessons for Africa Through a FAO Study Tour Draft Report International Commission on Irrigation and Drainage.

Islam, T., & Meade, N. (2013). The impact of attribute preferences on adoption timing: The case of photo-voltaic (PV) solar cells for household electricity generation. Energy Policy, 55, 521-530

Jager, W. (2006). Stimulating the diffusion of photovoltaic systems: A behavioural perspective. Energy Policy, 34(14), 1935-1943.

Lesser, J. A., & Su, X. (2008). Design of an economically efficient feed-in tariff structure for renewable energy development. Energy Policy, 36(3), 981-990.

Lobel, R., & Perakis, G. (2011). Consumer choice model for forecasting demand and designing incentives for solar technology. Available at SSRN, 1748424, 1-42.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. Journal of Applied Econometrics, 15(5), 447-470.

Ministry of New and Renewable Energy, Government of India (2019). Guidelines for implementation of PM KUSUM F.No – 32/645/2017-SPV division 22 July 2019, New Delhi.

Ministry of New and Renewable Energy, (2022a). Lok Sabha Unstarred question 2736 dated 17.03.22, New Delhi.

Ministry of New and Renewable Energy, (2022b). Lok Sabha Unstarred question 4692 dated 30.03.22, New Delhi.

Ministry of Power (2021). Annual Report 2021-22 Government of India, New Delhi.

Moosavian, S. M., Rahim, N. A., Selvaraj, J., & Solangi, K. H. (2013). Energy policy to promote photovoltaic generation. Renewable and Sustainable Energy Reviews, 25, 44-58.

La Nauze, A. (2016). Power from the people: opportunity cost and income fungibility in solar homes. Job Market Paper, University of Melbourne.

Navrud, S., & Bråten, K. G. (2007). Consumers' preferences for green and brown electricity: a choice modelling approach. Revue d'économie politique, 117(5), 795-811.

Noumon, T. C. A. (2008). Irrigation Schemes Using Solar Energy: A Case Study in Togb Irrigation Schemes Using Solar Energy: A Case Study in Togblo, District of Athieme District of Athieme–Province of Mono Province of Mono Province of Mono–Benin (Doctoral dissertation, Karlsruhe Institute of Technology).

Punjab Energy Development Agency (2020). Information Brochure & Application Form for Installation of Off-Grid Solar Pumps both surface and submersible pumps for irrigation in agriculture sector (Punjab) under component-B of PM-Kusum scheme, Chandigarh.

Punjab Energy Development Agency (2022). Benefits of solar pumps for farmers https://www.peda.gov.in/benefits-of-solar-pump-for-farmers, Chandigarh.

Punjab State Electricity Regulatory Commission (2020). Petition under Section 62 of the Electricity Act, 2003 for Determination of Levellised feed in Tariff in terms of PMKUSUM Scheme for Solarisation of 3900 Grid connected agriculture pumps in the State of Punjab under Component –C Petition No. 07 dated 15.02.2020.

Punjab State Electricity Regulatory Commission (2022). Petition under Section 62 of Electricity Act, 2003, determination of levelized ceiling tariff for setting up grid connected solar power plants ranging from 500 KW to 5 MW for feeder-level solarization of grid connected agriculture pumps under Component C in Punjab. Dated 13.04.2022.

Revelt, D., & Train, K. (1998). Mixed logit with repeated choices: households' choices of appliance efficiency level. Review of Economics and Statistics, 80(4), 647-657.

Rouvinen, S., and J. Matero. Stated Preferences of Finnish Private Homeowners for Residential Heating Systems: A Discrete Choice Experiment: Section on Bioenergy Markets. Biomass & Bioenergy 57 (2013): 22-32.

Rubio-Aliaga, A., Molina-Garcia, A., Garcia-Cascales, M. S., & Sanchez-Lozano, J. M. (2019). Net-metering and self-consumption analysis for direct PV groundwater pumping in agriculture: A Spanish case study. Applied Sciences, 9(8), 1646.

Ryan, M., Kolstad, J. R., Rockers, P. C., & Dolea, C. (2012). How to conduct a discrete choice experiment for health workforce recruitment and retention in remote and rural areas: a user guide with case studies (No. 74489, 1-94). The World Bank.

Sahu, B. K. (2015). A study on global solar PV energy developments and policies with special focus on the top ten solar PV power producing countries. Renewable and Sustainable Energy Reviews, 43, 621-634.

Sandwell, P., Chambon, C., Saraogi, A., Chabenat, A., Mazur, M., Ekins-Daukes, N., & Nelson, J. (2016). Analysis of energy access and impact of modern energy sources in unelectrified villages in Uttar Pradesh. Energy for Sustainable Development, 35, 67-79.

Scarpa, R., & Willis, K. (2010). Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. Energy Economics, 32(1), 129-136.

Shao, X., & Fang, T. (2021). Performance analysis of government subsidies for photovoltaic industry: Based on spatial econometric model. Energy Strategy Reviews, 34, 1-7.

Shirsath, P. B., Saini, S., Durga, N., Senoner, D., Ghose, N., Verma, S., & Sikka, A. K. (2020). Compendium on solar powered irrigation systems in India. CGIAR Research Program on Climate Change, Agriculture and Food Security, New Delhi, India.

Shah, T. (2018). Kick-starting the Kisan Urja Suraksha evam Utthaan Mahabhiyan. Economic and Political Weekly, 54, 13-16.

Shah Kashish (2021). A Renewed Push on Solar-Powered Irrigation Would Accelerate India's Energy Transition, Institute for Energy Economics and Financial Analysis Report, IEEFA, 1-59.

Siyaranamual, M., Amalia, M., Yusuf, A., & Alisjahbana, A. (2020). Consumers' willingness to pay for electricity service attributes: A discrete choice experiment in urban Indonesia. Energy Reports, 6, 562-571.

Sreewirote, B., Noppakant, A., & Pothisam, C. (2017, May). Performance and economic analysis of solar water pump system. In 2017 2nd International Conference Sustainable and Renewable Energy Engineering (pp. 73-77). IEEE.

Tongsopit, S., Junlakarn, S., Wibulpolprasert, W., Chaianong, A., Kokchang, P., & Hoang, N. V. (2019). The economics of solar PV self-consumption in Thailand. Renewable Energy, 138, 395-408.

Train, K. E. (2009). Discrete choice methods with simulation. Cambridge University Press.

Train, K., & Weeks, M. (2005). Discrete choice models in preference space and willingness-to-pay space. In Applications of simulation methods in environmental and resource economics (pp. 1-16). Springer, Dordrecht.

Wang, S. (2020). Current status of PV in China and its future forecast. CSEE Journal of Power and Energy Systems, 6(1), 72-82.

Wasi, N., & Carson, R. T. (2013). The influence of rebate programs on the demand for water heaters: The case of New South Wales. Energy Economics, 40, 645-656.

Yamaguchi, Y., Akai, K., Shen, J., Fujimura, N., Shimoda, Y., & Saijo, T. (2013). Prediction of photovoltaic and solar water heater diffusion and evaluation of promotion policies on the basis of consumers' choices. Applied Energy, 102, 1148-1159.

Yoo, S. H., & Kwak, S. Y. (2009). Willingness to pay for green electricity in Korea: A contingent valuation study. Energy Policy, 37(12), 5408-5416.

Zarnikau, J. (2003). Consumer demand for 'green power' and energy efficiency. Energy Policy, 31(15), 1661-1672.

Zhang, D., Chai, Q., Zhang, X., He, J., Yue, L., Dong, X., & Wu, S. (2012). Economical assessment of large-scale photovoltaic power development in China. Energy, 40(1), 370-375.

Zhai, P. (2013). Analyzing solar energy policies using a three-tier model: A case study of photovoltaics adoption in Arizona, United States. Renewable Energy, 57, 317-322.

Figure 5:13 Interaction terms

Sixty_Reb	Coef.	Std. Err.	Coef.	Std. Err.
	Random Effects Probit		Conditional Logit	
Low load	-.1796	.1561	-.3375	.2887
Medium load	-.3097*	.1667	-.6102**	.3069
High load	-.6918**	.2756	-1.3831**	.5385
Seventy_Cas				
Low load	-.3211**	.1529	-.5271*	.2816
Medium load	-.1286	.1759	-.0362	.3431
High load	-.0241	.2876	.1792	.5990
Seventy_Reb				
Low load	-.5177**	.1275	-.8240**	.2086
Medium load	-.7741**	.1382	-1.315**	.2260
High load	-.9469**	.2113	-1.5892**	.3448
Rate				
Low load	.0867**	.0318	.1454**	.0482
Medium load	.1938**	.0343	.2889**	.0519
High load	.1429**	.0516	.2636**	.0769
Sixty_Reb				
Single well	-.0946	.1709	-.2315	.3151
Multiple well	-.2262	.1661	-.4520	.3047
Seventy_Cas				
Single well	-.1252	.1657	-.2416	.3055
Multiple well	-.0775	.1658	-.0664	.3119
Seventy_Reb				
Single well	-.3108**	.1394	-.5591**	.2274
Multiple well	-.6471**	.1364	-1.1088**	.2226
Rate				
Single well	.0334	.0346	.0682	.0521
Multiple well	.1326**	.0338	.2045**	.0508
Sixty_Reb				
Marginal	-.2263	.2272	-.4440	.4130
Small	-.3859*	.2111	-.7844**	.3935
Semi medium	-.1374	.1990	-.2955	.3592
Medium	-.1147	.2031	-.2790	.3670
Large	-.2866	.2374	-.5639	.4256
Seventy_Cas				
Marginal	-.2063	.2339	-.2705	.4378
Small	-.1911	.2098	-.2724	.3884
Semi medium	-.4049*	.2041	-.6404*	.3772
Medium	-.0105	.2162	.0818	.4099
Large	.0926	.2785	.4594	.5819
Seventy_Reb				
Marginal	-.0040	.1898	-.0051	.3073
Small	-.0188	.1717	-.0125	.2785

Semi medium	-.1851	.1682	-.3785	.2727
Medium	-.1575	.1716	-.3830	.2783
Large	-.3958*	.2012	-.7014*	.3263
Rate				
Marginal	.1008**	.0468	.1131	.0696
Small	.0423	.0424	.0499	.0633
Semi medium	.0976**	.0414	.1316**	.0618
Medium	.0905**	.0423	.1153*	.0630
Large	.1636**	.0495	.2204**	.0736
Sixty_Reb				
Upto Matriculation	-.0382	.1710	-.0227	.3240
Upto Graduation	-.0942	.1754	-.0962	.3316
Above Graduation	.0757	.2895	.2002	.5273
Seventy_Cas				
Upto Matriculation	-.2530	.1670	-.3893	.3099
Upto Graduation	-.1725	.1734	-.2238	.3242
Above Graduation	.6510	.4331	1.667	1.068
Seventy_Reb				
Upto Matriculation	-.2267*	.1375	-.4108*	.2228
Upto Graduation	-.2505*	.1412	-.4729**	.2289
Above Graduation	-.1559	.2429	-.4718	.3940
Rate				
Upto Matriculation	.0938**	.0340	.1224**	.0508
Upto Graduation	.1136**	.0349	.1433**	.0521
Above Graduation	.0912	.0600	.0954	.0888

** p < .10, **p < 0.05*

Figure 5:14 Estimated parameters and WTP - Random Effects Probit

Choice	Coef.	Std. Err.	WTP	Std. Err.
1.Sixty_Reb	-1.0070***	.0513	-2.1753***	.1950
1.Seventy_Cas	1.6965***	.0541	3.6649***	.2965
1.Seventy_Reb	.1106***	.0436	.2390***	.0960
Rate	.4629***	.0356		
const	-1.7838***	.1162		
_cons	.08399***	.0151		
/lnsig2u	-25.59121	5877.		
sigma_u	2.77e-06	.0081		
rho	7.69e-12	4.52e-08		

Figure 5:15 Marginal Effect - Random Effects Probit and Conditional Logit

Attribute	Mean	Std. Err.	Mean	Std. Err.
	Random effects probit		Conditional logit	
Sixty_Reb	-0.3370***	.0165	-0.357***	0.018
Seventy_Cas	0.5678***	.0163	0.60***	0.019

Seventy_Reb	0.0370***	.0145	0.038***	0.014
Rate	0.1549***	.0117	0.167***	0.012

Figure 5:16 Predicted Probabilities - Random Effects Probit and Conditional Logit

	Random effects probit		Conditional logit	
	Margin	Std. Err.	Margin	Std. Err.
Sixty_Reb	.2146***	.012	.2007***	.011
Seventy_Cas	.9100***	.007	.9061***	.007
Seventy_Reb	.5314***	.013	.5159***	.012

Figure 5:17 WTP Space Results

Choice	Coefficient	Std. err.
Mean	-40.132***	9.741
Sixty_Reb	64.178***	15.17
Seventy_Cas	.5962	.6426
Seventy_Reb	-2.591***	.1704
mRate		
SD		
Sixty_Reb	-10.773***	3.622
Seventy_Cas	20.681***	5.175
Seventy_Reb	4.600***	1.225
mRate	1.1750***	.1612

Questionnaire 4

1 If there is subsidy of 60% on 7.5 HP solar pump, you would have to only invest Rs. 164000 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 8025 kWh could be sold at buyback rate of Rs. 2.6/kWh, which would give additional income of Rs. 20865 per year. You would be able to recoup the investment in 7.8 years and earn annual income of Rs. 20865 in cash for remaining 12.2 years. Second benefit would be receiving daytime solar power at your convenience.

If there is subsidy of 60% on 10 HP solar pump, you would have to only invest Rs. 212000 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 10519 kWh could be sold at buyback rate of Rs. 2.6/kWh, which would give additional income of Rs. 27350 per year. You would be able to recoup the investment in 7.75 years and earn annual income of Rs. 27350 in cash for remaining 12.25 years. Second benefit would be receiving daytime solar power at your convenience.

Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

2. In the above scheme, you can receive buy back income of Rs. 20865 or Rs. 27350 as offset in your domestic bill. Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything,

nor would you receive any additional buyback income?
Yes or No

3 If there is subsidy of 75% on 7.5 HP solar pump, you would have to only invest Rs. 102500 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 8025 kWh could be sold at buyback rate of Rs. 2.6/kWh, which would give additional income of Rs. 20865 per year. You would be able to recoup the investment in 4.9 years and earn annual income of Rs. 20865 in cash for remaining 15.1 years. Second benefit would be receiving daytime solar power at your convenience.

If there is subsidy of 75% on 10 HP solar pump, you would have to only invest Rs. 132500 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 10519 kWh could be sold at buyback rate of Rs. 2.6/kWh, which would give additional income of Rs. 27350 per year. You would be able to recoup the investment in 4.8 years and earn annual income of Rs. 27350 in cash for remaining 15.2 years. Second benefit would be receiving daytime solar power at your convenience.

Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

4 In the above scheme, you can receive buy back income of Rs. 20865 or Rs. 27350 as offset in your domestic bill. Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

5 If there is subsidy of 60% on 7.5 HP solar pump, you would have to only invest Rs. 164000 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 8025 kWh could be sold at buyback rate of Rs. 3.6/kWh, which would give additional income of Rs. 28890 per year. You would be able to recoup the investment in 5.6 years and earn annual income of Rs. 28890 in cash for remaining 14.4 years. Second benefit would be receiving daytime solar power at your convenience.

If there is subsidy of 60% on 10 HP solar pump, you would have to only invest Rs. 212000 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 10519 kWh could be sold at buyback rate of Rs. 3.6/kWh, which would give additional income of Rs. 37868 per year. You would be able to recoup the investment in 5.5 years and earn annual income of Rs. 37868 in cash for remaining 14.5 years. Second benefit would be receiving daytime solar power at your convenience.

Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

6 In the above scheme, you can receive buy back income of Rs. 28890 or Rs. 37868 as offset in your domestic bill. Would you prefer to install individual gridconnected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?

Yes or No

7. If there is subsidy of 75% on 7.5 HP solar pump, you would have to only invest Rs. 102500 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 8025 kWh could be sold at buyback rate of Rs. 3.6/kWh, which would give additional income of Rs. 28890 per year. You would be able to recoup the investment in 3.5 years and earn annual income of Rs. 28890 in cash for remaining 16.5 years. Second benefit would be receiving daytime solar power at your convenience.

If there is subsidy of 75% on 10 HP solar pump, you would have to only invest Rs. 132500 for installing grid connected solar pump. After fulfilling your irrigation requirements, surplus solar power of 10519 kWh could be sold at buyback rate of Rs. 3.6/kWh, which would give additional income of Rs. 37868 per year. You would be able to recoup the investment in 3.4 years and earn annual income of Rs. 37868 in cash for remaining 16.6 years. Second benefit would be receiving daytime solar power at your convenience.

Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

8. In the above scheme, you can receive buy back income of Rs. 28890 or Rs. 37868 as offset in your domestic bill. Would you prefer to install individual grid connected solar pump or prefer to receive solar power from solar agriculture feeder set up by government sponsored private developer, where you would not have to invest anything, nor would you receive any additional buyback income?
Yes or No

Other questions:

1. What difficulties are you facing in regard to power supply?
Yes or No

2. In your opinion, how can the electricity supply be improved?

(a) Regular supply

(b) Advance intimation of breakdown

(c) Day-time supply

(d) Proper treatment by line staff

(e) Increase in number of supply hours.

(f) Any other suggestion

3. Do you think free power should be withdrawn from Pensioners, Govt servants, MLAs/MPs, persons on constitutional posts, income tax payees, persons drawing non-agricultural income?
Yes or No

4. Do you agree that there should be restrictions on drawl or pricing of water?
Yes or No

6. Chapter: Conclusions- Reform is possible

The current rates of groundwater use in Punjab are unsustainable in the long run. It is predicted that the state, which draws a major part of its revenue from agriculture, could run out of water and turn into a desert in the next 25 years if the present pace of drawing water from underground aquifers continues. Sustainable agriculture through more efficient use of resources and with minimal impact on the environment is of crucial importance. It is felt that inducing behavioral change provides a natural focus to meet the goal of sustainable development, protecting livelihoods, saving water for future generations, and averting the looming desertification crisis. For years, policymakers and researchers have been advocating reforms, which have remained politically intractable so far in the face of stiff opposition from farmers. This behavioral research presents firsthand evidence of the feasibility of rationalizing free electricity and reducing the area under water-guzzling crops in Punjab. The emerging findings represent a potential opportunity to break this impasse.

Description of the Study and the Methodology: The dissertation applies four discrete choice experiments to examine three critical issues: switch to low-water crops; shift to metered supply; and transition from fossil fuel to solar energy in Punjab agriculture. The three projects reported in the thesis were chosen as they shed light on the intertwined nature of challenges confronting water, food, and energy sectors in developing countries, and also place farmers' preferences and behavioral responses at the heart of the transition process. These econometric studies illustrate that farmers' preferences for financial incentives to motivate water and energy savings are heterogeneous. That being so, differentiated incentives and subsidies can promote farmers' acceptability of conservation strategies and foster efficiency gains for society. The research finds that an understanding of heterogeneity in farmer preferences can help reconcile farmers' preferences while improving overall social efficiency.

The discrete choice method is a fruitful approach for a better understanding of farmer adoption behavior and has the potential to establish new interventions for sustainable resource use. Used widely across several disciplines, this statistical technique is well suited to investigate the potential acceptability of energy-saving behavior and study the heterogeneity of farmers' preferences for choosing certain interventions. There are genuine trade-offs, for instance, yield maximization leads to reduced water use efficiency, better returns can promote higher willingness to pay, etc. Choice modeling uncovers trade-offs and highlights that public net benefits can be highly positive if private net costs are compensated, even if net fiscal zero is not achieved, as the environmental cost of inaction can be unacceptably high. In the three chapters, micro-level choice data has been exploited to econometrically infer perceived utility; overall benefit, and trade-offs between attributes of different alternatives. Acceptance rates are high reflecting the desire of farmers to make necessary behavioral changes under certain circumstances. Measures to foster greater uptake are recommended to elicit consensus and achieve the desired goals.

6.1 Examining the effect of compensation payments in inducing shift to low water rice varieties and influencing willingness to pay: Chapter 3 is titled, 'Discrete choice experiment to estimate farmers' preferences for low-water rice variety in Punjab'. It examines farmers' preferences for adopting low-water rice variety given that the marginal cost of pumping groundwater is effectively zero with the current policy of free electricity to agriculture in Punjab. The aim of the study is to estimate preferences for economic incentives, offered as area-based payment and minimum assured price to adopt low-water rice varieties (short duration rice and basmati rice variety) and willingness to trade off free electricity for these incentives. This behavioral change has the potential to lower electricity consumption, slow down groundwater depletion and reduce carbon footprint in the groundwater rural economy of Punjab.

The estimation strategy applied conditional logit and random effects probit model which relaxes the IIA assumption. Choice data analyzed farmers' valuations for area-based payments for adopting short-duration rice variety - PR 121/126 and minimum assured prices for adopting a low-water basmati rice variety. The main finding is that farmers are likely to adopt low-water rice varieties which can potentially increase net social benefit if the net private cost can be compensated to some extent. The results show that providing price support is considered helpful to farmers in hedging risk and compensating them for the potential losses suffered by replacing the high-water intensive rice variety with the low-water rice variety, which has lower yield and consequently lower returns. The chapter illustrates that the offer of a moderate economic incentive to replace high water intensive rice variety is acceptable to 75 percent of the farmers. Preventing farmers from falsely presenting the long-duration variety to claim incentive payments is likely to be an implementation challenge in promoting diversification. Real-time crop monitoring and strengthening inter-institutional coordination may help to prevent the misuse of incentive schemes. In essence, the study shows the way for mitigating the adverse economic impact of adopting sustainable crop choices on farmers livelihoods by adjusting the level of compensation for adopting less water intensive crop cultivation in groundwater scarce regions.

The study explores and builds on the association between willingness to pay for electricity and compensation payments for adopting low-water rice variety. Any study on reduction of subsidy is incomplete without presenting strategies to recover revenue from consumption. This study examines farmers preferences for accepting two power tariff modes - fixed monthly charge and load-based charge along-with incentive payments for shifting crop variety. The findings show that at least 56 percent of the farmers show a preference to pay monthly electricity charges or load-based tariffs with the offer of area-based payment and minimum assured price for substituting high water rice with low water rice variety.

The chapter also highlights that the type of the electricity charge is important for inducing payment behaviour. 66 percent of the farmers are inclined to accept fixed monthly electricity charge as compared to a load-based tariff. Flat-rate electricity charges do not require metering and therefore are more acceptable to farmers. Further, they are economical and less labor intensive for utilities, though they are less advantageous from groundwater conservation point of view. This study found that the offer of an economic incentive can incentivize farmers to diversify to low-water crops and instill some degree of willingness to pay for electricity.

At an aggregate level, farmers are willing to pay/willing to accept the fixed charge of Rs. 99 ($1.24) per month and Rs. 112 ($1.4) per month, and the load-based tariff of Rs. 8.38($0.10)/HP/month and Rs. 9.45 ($0.11)/HP/month for the two levels of area-based payment. WTP/WTA is Rs. 74 ($0.92) per month and Rs. 137 ($1.72) per month for two levels of minimum assured price for basmati. The WTP/WTA for load-based tariff at Rs. 4 ($0.05)/hp/month and Rs. 7.6 ($0.09)/HP/month Is lower for minimum assured prices for adopting basmati.

When the present analysis is disaggregated by region and farm characteristics, the findings give further directions for reform. Farmers in Punjab's north-eastern Majha belt show higher valuations for minimum assured prices to adopt the basmati rice variety. This region is considered most suitable for basmati cultivation because of the agro-climatic and marketing advantage. On the other hand, the Malwa region which has been described as India's 'cancer capital' due to the high concentration of pesticide residues and is known for widespread cultivation of long-duration paddy variety, prefers area-based payment for short-duration variety. Farmers in the Majha region show lower negative preferences for willingness to pay for electricity.

Disaggregating the findings with respect to the socio-economic and demographic characteristics of farmers suggests differentiated preferences between educated and uneducated households. Educated farmers are more likely to behave in an environmentally friendly manner. Education has a positive effect on the willingness to pay for electricity, besides inducing adoption of low-water rice varieties. Farmers with university degrees are significantly more likely to pay monthly electricity charge and load-based tariff on the offer of area-based payment and minimum assured price for adopting low-water rice variety. Marginal and medium farmers and multiple tube well-owning farmers significantly prefer load-based electricity tariffs, while farmers with high loads have significantly negative preferences for paying monthly electricity and load-based tariff with the offer of area-based payment. This is a crucial lesson for policy makers as identifying farmers and regions with a higher willingness to adopt sustainable behavior will provide scope for introducing reform.

Further, the econometric analysis of valuations for different economic incentives found a higher probability of adopting the basmati variety. Farmers cultivating PUSA 1509 variety were more likely to agree to pay for electricity with the offer of a minimum assured price. A policy prescription is that supply of free electricity could be made conditional upon adopting water-efficient cropping practices and farmers could be asked to pay for electricity if they continue to grow high water crops.

This chapter highlights the importance of compensation scheme in promoting diversification and determines the potential costs and effects of incentive attributes on preferences. A lesser number of attributes were used in the study to minimize cognitive burden and task complexity. Future research could explore the role of non-monetary attributes in adoption and assess farmers' preferences for other crops and power tariff modes, which can lead to better informed agricultural and ecologically valuable land use policy.

6.2 Can cash incentives and annual limits on free electricity modify farmers' pumping behaviour? Exploring this crucial question, chapter 4 titled 'Using rewards and penalties to incentivize sustainability in agriculture – Evidence from a discrete choice experiment in Punjab' applies the estimation strategy developed in Chapter 3 to uncover farmers' preferences for accepting metered consumption as opposed to the current policy of unmetered and unlimited supply of free electricity for irrigation in Punjab. As Punjab farmers receive free power, there is little incentive for them to shift to metered consumption unless presented with a more attractive proposition. In order to minimize the effect of unlimited supply of free electricity in driving excessive extraction of groundwater, there is a need to restructure the distribution of free farm power. Specifically, the chapter examines preferences for accepting minimum annual limit of free electricity with a reward for saving electricity and metered charge on consumption beyond the limit. This is likely to achieve a balance between farmer welfare, groundwater sustainability and energy accounting.

This study found significant heterogeneity in valuations for different levels of annual limit of free electricity and cash incentive for saving electricity as opposed to unmetered consumption. The acceptance rate is 27 percent for 1500 kWh/acre and 71 percent for 1550 kWh/acre free electricity entitlement combined with a cash incentive of Rs. 2 ($0.025)/kWh and electricity tariff of Rs. 1 ($0.01)/kWh. As expected, the acceptance rate increased to 82 percent and 84 percent with a cash incentive of Rs. 3($0.03))/kWh and electricity tariff of Rs. 1($0.01)/kWh and Rs. 2($0.02)/kWh respectively. Paying a nominal tariff was not perceived to be welfare-reducing, particularly when combined with an improved limit of free electricity and cash incentive for saving energy. A relatively moderate cash incentive of Rs. 2 for each unit of electricity saved was found to be successful in motivating farmers to accept the annual limit of free electricity and tariff of Rs. 1/kWh on exceeding the limit.

A policy prescription is that it would be easier to Implement annual limit of free electricity sufficient for crop growth when combined with reward payments, notwithstanding the imposition of a 'dissuading' electricity tariff. Electricity tariffs and ceilings on free electricity may not necessarily face socio-political opposition if accompanied by cash incentives to reward behavioral change.

The econometric analysis shows a progressive increase in perceived utility as the farmer moves from a lower level of annual limit and cash incentive to progressively higher levels. Farmers are willing to sacrifice Rs. 4.6 ($0.05)/kWh to receive 1550 kWh/acre and cash incentive of Rs. 3($0.037)/kWh; Rs. 4.3($0.053)/kWh to receive 1550/acre free electricity and cash incentive of Rs. 2($0.02)/kWh and Rs. 2.5($0.031)/kWh for 1500 kWh/acre and Rs. 3($0.03)/kWh cash incentive.

Since there is considerable variation in agro-climatic conditions and groundwater availability across the regions in Punjab, the location-specific heterogeneity in preferences is examined for rationalizing the free farm power policy. Farmers in Doaba, the region between the two rivers show the highest preferences for accepting annual free electricity limit with a cash incentive. This region is known for the most fertile soil, small landholdings, a higher share of educated people and large number of people from this region are settled in other countries.

The study found that education is an important predictor of the preferences for moving away from unmetered supply of free electricity. Better educated farmers are more likely to accept annual free electricity limit with cash incentives for saving electricity. This implies that education ahead of implementation might help in motivating farmers in accepting metered consumption.

The emerging evidence of preference heterogeneity could be useful to policy makers in taking targeted measures to tailor the provision of free electricity. From a policy maker's perspective, the annual limit of free electricity could be offered to relatively large and medium farmers. Our literature review shows that the benefits of free electricity are heavily tilted towards the medium and large farmers in the current policy framework. About 20 percent of the farmers possessing relatively larger land holdings consume 50 percent of the free electricity in Punjab. It is estimated that removing the free electricity supply to multiple tube well owners could reduce expenditure on electricity subsidy by 14 percent. Targeted strategies can potentially solve the problems plaguing the existing power tariff structure in Indian agriculture.

In a developing country, there are trade-offs between achieving economic efficiency, and other economic objectives such as revenue adequacy for the utility and affordability of the service for impoverished farmers. The cost-benefit analysis carried out in the fourth chapter demonstrated that combining the strategy of offering annual limit of 1550 kWh free electricity per acre with Rs. 2 ($0.025) cash incentive for saving electricity and electricity tariff of Rs. 1($0/01)/kWh on over consumption can balance the divergent objectives of reducing financial burden on the government, providing free electricity for agriculture development and conserving groundwater and energy resources. The saving in electricity subsidy bill for the government could compensate for the fiscal cost of introducing incentive-based metered consumption across the state. Accounting for environmental valuation, this has the potential to ease pressure on aquifers and reduce carbon emissions in Punjab.

Literature review shows that raising the opportunity cost of electricity for pumping groundwater can function as de facto regulation of groundwater use and reduce the common pool externality. Building on this work, this study demonstrates that exposing the farmer to annual electricity limit fixed for use and awarding economic incentives for unused units of power less than the limit can create the marginal value of pumping additional units of groundwater, at least in wealth terms, which can potentially translate into reduced demand for electricity and provide a net social benefit in groundwater stressed areas. Therefore, the carrot and stick approach, applied by offering incentive for accepting metering and reducing consumption, and imposing electricity tariff to check excessive use of electricity can reduce the gap between socially optimal and myopic groundwater use and management outcomes.

Further research could realistically determine the annual limit of free electricity based on the sustainable yield of the aquifer, crops grown, and irrigated land. The average expected electricity consumption could be used as a reference, instead of the previous year's consumption level to avoid discriminating against consumers who have already reduced consumption to their lowest possible level. Interventions and nudges can be shaped to make incentive and penalty-based tariffs more attractive. It is evident that cash incentives and minimum free electricity entitlements may be able to reduce electricity consumption, however strategies involving compensation payments to encourage cultivation of low-water intensive crops would need to be simultaneously implemented to reverse the unabated trend of groundwater depletion in Punjab. The findings of this chapter can feed into future research in which farmer heterogeneity could be exploited for complementing the annual free electricity limit and cash incentives with simultaneous adoption of sustainable strategies such as short-duration paddy varieties, direct seeded rice, laser land leveling, alternate wet and dry irrigation, solar agriculture pumps, etc. for reducing groundwater usage.

In conclusion, the findings of this study provide firsthand insight about farmers preferences for accepting annual free electricity limit and reward-penalty based electricity tariffs to restructure the free farm power policy in Punjab. The study found that rewards (carrot) and punishments (stick) can complement each other and designing a behavioral intervention around rewards only and omitting an option for punishment may be a mistake, even if in the end punishments are rarely used. Another significant lesson is that the stimulus for willingness to pay and adopt metered consumption would come from improved supply, particularly at the critical periods of growth.

6.3 Grid connected solar irrigation pumps – A solution to water management in water stressed areas: Chapter 5, 'Farmers preferences for incentives on solar pumps: Evidence from a choice experiment in Punjab' adds another dimension to the search for an environmentally sustainable balance within the energy-water-agriculture nexus. Solar PV pumps can be a viable alternative to electric pumps. The chapter examines farmers' preferences for penetration of solar PV pumps in agriculture and sheds light on which economic incentives can potentially encourage the replacement of electric pumps by solar PV irrigation pumps that offer a cost effective and sustainable energy solution. State policies such as subsidies and other incentives can overlook the negative impact of solar irrigation pumps on the environment caused by groundwater over-abstraction. Therefore, a conundrum arises, on the one hand subsidies are required if this technology is to be made accessible to all, but on the other hand the policies need to account for the impact of this technology on groundwater resources. The recommendation at the end of the chapter is that subsidies may need to be targeted and accompanied by mechanisms to check groundwater over-abstraction.

The econometric analysis based on conditional logit and mixed logit estimation found that the financial limitation is the major barrier undermining the expansion of this technology, though there is high level of acceptance/interest amongst farmers. As the high initial cost of individual solar pump is a significant barrier, solar irrigation pumps can represent a viable option for farmers when sufficient direct incentives are provided through government policies such as subsidies, low interest loans etc. The discrete choice experiment collected evidence of positive and significant preference for enhancing the existing subsidy to seventy-five percent of the capital cost of individual solar irrigation pump. On the other hand, the preferences for feeder-level solarization are lower, except in cases where the capital subsidy on an individual solar pump is perceived to be low.

Given the heavy initial capital cost, enhanced subsidy is a highly significant predictor of individual adoption as 91 percent of the respondent farmers showed preference for grid-connected solar agriculture pumps with higher subsidy component of seventy-five percent. The acceptance rate for the existing level of sixty percent subsidy on initial capital cost of solar irrigation pump Is considerably lower at 35 percent. Comparatively speaking, policy measures designed to reduce initial installation costs are preferred over subsequent monetary gains from pump operation.

An indirect way to help boost the demand for solar irrigation pumps is to create incentives for farmers to sell the electricity generated by solar PV pumps through feed-in-tariffs. Further introduction of solar pumping is raising concerns due to the already existing over-abstraction of groundwater in developing countries. Attractive levelized tariff policies and surplus power purchase options can limit groundwater pumping in irrigation. With the current policy thrust on off grid solar, the chapter examines farmers preferences for the introduction of grid connected solar pumps with energy buyback option. This choice experiment conducted in this study delivers empirical evidence on the importance of the feed-in-tariff rate in driving the introduction of solar irrigation pumps. Positive and significant preferences of farmers are observed for the buyback of surplus solar power at two feed-in-tariff rates of Rs. 2.6 ($0.032)/kWh and Rs. 3.6 ($0.045)/kWh, which can promote adoption. A policy prescription from this finding is that attractive feed-in-tariff rates can serve a dual purpose of promoting solar PV technology by creating income for 'Prosumers' - farmers turned electricity producers, and lowering the environmental cost of indiscriminate water extraction.

Direct and indirect incentives can be active policy decisions for promoting solar pumping. Policymakers can build upon the trade-offs between the feed-in-tariff rate, the effect of perceived risk reduction on farmers' investment behavior, and the opportunity cost of groundwater pumping. Future research could investigate preferences for feed-in-tariff rates differentiated by season and region as a more cost-effective way to promote groundwater conservation.

Feed-in-tariffs can be an effective way to increase solar energy generation and use in agriculture. At the same time, identifying preferences for income transfer from 'solar farming' either as money payment or as an offset in household electricity bill can be useful for decision makers who want to advance renewable energy policy in agriculture. The discrete choice experiment found that farmers in Punjab value income transfer in cash more than offset in domestic electricity bill. This result can be exploited for targeted resource allocations to stimulate future adoption.

The estimation strategy applied in this chapter shows that the capital subsidy effects willingness to pay/willingness to accept valuations. The willingness to pay/willingness to accept is Rs. 3.8 ($0.047)/kWh for seventy-five percent capital subsidy on the solar pump with cash income and Rs.0.17 ($0.002)/kWh for seventy-five percent subsidy with offset in the residential bill. Farmers may need to be compensated ($0.03/kWh) for accepting lower subsidy of sixty percent.

The estimation strategy examines socio-economic and location-specific determinants affecting solar energy adoption decisions. Indicating significant heterogeneity in preferences, preferences to sell the electrcity generated by solar pumps through feed-in-tariff increase with load capacity and tube well ownership of farmers. Farmers with degrees and medium and large farmers are significantly more likely to prefer the buyback of surplus solar power. The main implication is that education has a positive effect on solar energy adoption. Therefore, initial targeting of younger and more educated farmers would promote solar energy adoption and have a demonstration effect on other farmers.

Further, farmers preferences cannot be pooled together across different agro-climatic zones. The results show that respondents in Punjab's Majha region are more likely to choose grid-connected solar irrigation pumps with a buyback option. Majha region is known for the small size of average landholding (58% own about 2-hectare land), highest surface water irrigation, and relatively less severe impact of groundwater depletion.

To summarize, without attractive incentives, the development of solar energy in agriculture would be hindered. At the same time, subsidies and incentives would need to be targeted and tied to water requirements and accompanied by monitoring mechanisms of maximum pump and extraction capabilities. As higher capital subsidy is at the heart of the policy to accelerate the transition to sustainable energy in agriculture, subsidy programs could be therefore, either universal or targeted. Soft loans for medium and large farmers could potentially help in increasing solar PV technology penetration in agriculture. The cost-benefit analysis conducted in the chapter shows that it is feasible to finance the additional expenditure on account of disbursing higher subsidies out of the electricity subsidy saved by switching to renewable energy source.

Further, policy makers may carefully consider which customer segments to target for accelerating solar pump adoption. Subsidized solar pumps can be offered to farmers awaiting the release of new connections and using diesel pumps which are more expensive and damaging to the environment. The life cycle cost analysis conducted in the chapter found that the annualized life cycle cost of a grid-connected solar pump is lower than that for a diesel pump. Secondly, extending the subsidy scheme to portable pumps could cater to both the farm and household energy needs of small farmers. Thirdly, considering that solar energy is reliable and beneficial for enhancing crop production, connecting solar PV to agriculture feeders could unlock their potential in rural areas. The study found that while farmers prefer installing individual pumps with seventy-five percent subsidy, feeder-level solarization can be an option for increasing power supply availability for agriculture during the daytime without subsidy support on individual pumps.

Lastly, weaning farmers away from electric irrigation pumps would reduce subsidy expenditure, improve financial viability of the utility, and provide an environmentally benign source of energy for meeting irrigation needs. Leveraging solar energy in agriculture emerges as a game changer from the energy-water-agriculture perspective.

The study found that creating awareness of the economic benefits, ensuring quality equipment, providing technical support about groundwater resources, optimal sizing of solar pumps, etc., and advising farmers about sustainable agricultural practices for large-scale deployment of pumps is equally important. Accelerated administrative approvals, longer duration of government support programs, and more communication and outreach campaigns can increase the attractiveness of solar pumps for farmers. Delivery of locally appropriate service delivery models needs to be further scrutinized in the context of socio-economic and institutional factors. An integrated approach is needed for the development of solar technology in agriculture for decision makers to address the development gaps, water sustainability concerns and energy needs.

Before discussing general conclusions, it would be prudent to mention that the findings of the three chapters can potentially provide the following key steps for unpacking subsidy reform and ensuring sustainable outcomes in Punjab:

1. Conduct pilot studies in regions which are positive about changing crop choices, energy mix and delivery of free electricity.

2. Educate the farmers and raise the level of awareness about the urgent need to repurpose input subsidy as financial support for less water intensive crops.

3.Raise economic incentives for low-water rice varieties to compensate farmers for any adverse impact on their livelihoods. Introduce minimum assured price for basmati cultivation as a replacement of high-water rice variety.

4. Enforce electrcity charge on high water rice variety in most groundwater stressed regions.

5. Building on these findings, introduce annual limits on free electricity and cash incentive with a mandatory 'payment on excess consumption' clause to begin with for medium and large farmers.

6. Delivery of solar energy in any model – individual or community level, with water extraction monitoring mechanism must become the major thrust area of the government. Designing business model innovations to match farmer preferences will hold the key to the energy mix transition.

7. While formulating a tariff policy, involve farmers in decision making as moderate fixed rates seem to be acceptable.

6.4: General conclusions

The final section presents some general conclusions and reflects on the potential policy directions to be adopted vis-a-vis the necessity to improve the financial and environmental sustainability of the proposed alternatives to the current free farm power policy.

a) Improved supply is an essential prerequisite, without which the economic benefit of inducing energy-saving behavior among Punjab farmers is not likely to translate into improved efficiency in the use of electricity and water, and better financial viability of the utilities. The utilities would have to make a credible commitment to improve the quality of supply as farmers adopt payment behavior. Future research could examine strategies to optimize the supply to match the preferences of farmers about the particular time and particular season of supply and account for spatial disparities in willingness to pay.

b) The stability of policy change over a medium term of 5-10 years would be important in attracting greater acceptance. Policies which require land use changes and technology adoption are likely to be more effective in inducing energy-saving behavior if they are guaranteed over some medium term.

c) Punjab has a strong tradition of organized peasant movements. Rich farmers through their initiative can mobilize the peasantry in general. There is a trade-off as they can be an important ally in any reform effort and withdrawing benefits from them can reduce support for any reform program. This study makes a good case for universal benefits to all by showing that small monetary incentives and slight increases in electricity tariffs can bring about behavior change and acceptance of proposed reform measures. While the incentives could have been more generous, however, the framework applied in these chapters presented scenarios where private net benefits were sufficiently positive to prompt the adoption of environmentally beneficial behavior and public net benefits were highly positive.

d) Further, the degree of trust in government institutions among Punjab farmers is low. It is observed that the majority of the farmers in Punjab have a positive attitude toward the conservation of water and the environment. Government institutions need to rethink their top-down strategies and pursue more inclusive policy-making responsive to local needs, thereby helping to restore trust among the farmers in the government. Sustainable solutions are not likely to be adopted unless they are profitable and focus on increased engagement with farmers. The probability of success could be increased if farmers are frequently consulted and provided information about alternative strategies. For instance, one area where participation could enhance compliance of farmers could be the selection and enforcement of appropriate technological solutions such as smart meters, pre-paid scratch cards, etc. to improve energy accounting in agricultural supply.

It would be prudent to say that this study provides evidence-based assessment about three specific interventions which can induce electricity and water savings. These solutions are by no means exhaustive, at best only illustrative. There is a rich potential for conducting other choice experiments to examine preferences for groundwater property rights, conjunctive use, and management of surface and groundwater resources, water-saving technologies and energy-efficient equipment, improved crop strains, zone-wise crop diversification, etc.

While the chapters provide empirical evidence and demonstrate the use of stated preference methods, however more granular data, and real choices about differentiated incentive schemes for different categories of farmers could extend this research further. Follow-up studies could identify more drivers of farmers' preferences. For instance, more work can be done on the exact calibration of the incentives. With more time at the researcher's disposal, future research might focus on preferences and valuations of more nuanced attributes and trade-offs with the help of more sophisticated estimation procedures.

In summary, these three chapters provide new insights into the importance of including farmer preference dynamics when formulating policies to encourage sustainable resource use in agriculture. The present study is valuable to both utilities and policymakers as these findings can translate to a promising intervention strategy to minimize consumption and promote sustainable behavior. In particular, the findings of this study will be especially beneficial as it is the first discrete choice study (to the best of the author's knowledge) conducted in Punjab, where information about incentivizing energy-saving behavior for sustainable agriculture is inescapably needed on an urgent basis. Smarter designs may exist in repackaging input subsidy as output price support. The government may seriously re-evaluate the desirability of investing scarce fiscal resources in input subsidization such as providing free electricity to agriculture. Repurposing electricity subsidy as output price support is likely to make farmers no worse off and the environment significantly better off.

The cost-benefit analysis conducted in all the three chapters offers directions for policymakers to finance incentive schemes by repurposing inefficient input subsidies and using freed-up resources in empowering farming communities for the healthy maintenance of the natural resources they possess for future sustainable use. As real custodians of natural resources, they realize the intensity of the problem and the appropriate institutional support needed to reverse the deterioration process. The econometric methods used, and the findings of this thesis show uptake for behavior change strategies among Punjab farmers, who are keenly aware of the cliff edge challenge confronting them and the need to quickly take sustainable decisions. The crucial challenge would be to exploit farmers' preference heterogeneity and conservation trade-offs for effective demand-side management. This study is a first step towards understanding environmental policy issues from a behavioral perspective and will hopefully lead to further research in examining sustainable solutions more fully.

A crucial lesson from this study is that farmers in general and educated farmers, in particular, are painfully aware of the disastrous consequences of continuing with the present practices and the prevailing subsidy regime. They are willing to change and accept needed reforms provided they do not have to suffer any financial losses in the process of change. This study can serve as an essential blueprint and in a way a wake-up call for policymakers who hesitate to undertake reform as they perceive stiff resistance from the major stakeholders. Apart from providing several valuable inputs, an important takeaway from this study is the need to choose a reform process that creates more winners than losers. Further, the study highlights the need to give up the feeling of despondency and inertia by the government and to proactively engage in a sustained meaningful dialogue with an open mind with all the stakeholders. The costs of further delaying the reform process will be unacceptably high.