Modelling farmer and consumer preferences for cleaner food production

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Abstract

Agriculture in Pakistan is currently unsustainable due to intensive farming practices – the concentrated use of agricultural inputs, including water and agrochemicals. The widespread use of intensive farming has dire effects on both human health and the natural environment. As such the antidote to these problems would be the adoption of sustainable agriculture. The present research proposes to reduce the use of agrochemicals such as pesticides and fertilisers, and adopt efficient irrigation technology in tomato cultivation in district Khushab Pakistan. Discrete choice experiment (DCE) approach is deployed to study farmer and consumer preferences and their valuation of the proposed changes to facilitate the adoption of sustainable agriculture in tomato cultivation. Questionnaire data is used to investigate farmer and consumer perceptions and understanding of existing farming practices and proposed changes.

Findings reveal that majority farmers and consumers are aware of the unfavourable health and environmental impacts of existing farming practices used in tomato cultivation. Empirical analysis of questionnaire data show that farmers who own their farmland and those who have received the training to apply agrochemicals are more likely to have a positive perception of the proposed changes. Likewise, consumers who have more awareness and information about different farming practices and a greater health consciousness are more keen to see the changes in existing farming practices. DCE analysis shows that farmers prefer the reduction in the use of pesticide and fertiliser use, but place a negative value on the adoption of drip irrigation. On the other hand, consumers not only prefer the proposed changes, but their willingness to pay (WTP) to implement the proposed changes is higher than the farmers' willingness to accept (WTA). This implies that the proposed changes in current farming practices used for tomato cultivation are economically viable, and hence that market-based approaches to control agricultural pollution may be more effective than regulations in Pakistan.

Table of contents

List of Figures

List of tables

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Chapter 1 Introduction

1.1 Preamble

Contemporary agricultural practices are unsustainable, in part due to intensive farming – i.e. concentrated use of agricultural inputs. This has adverse consequences for human health, the natural environment and agriculture itself. The antidote to this problem would be the adoption of sustainable agriculture which involves appropriate use of agricultural inputs unlike intensive farming. However, the implementation of sustainable agriculture in developing countries like Pakistan is challenging, mostly due to the difficulty in encouraging local adoption. Therefore, understanding local producer and consumer perceptions and how they make choices becomes a key factor for policy makers wishing to implement sustainable agricultural practices.

The objective of the present study is to understand the perceptions and choices of tomato farmers in Khushab and tomato consumers in Islamabad Pakistan when confronted with the option of adopting sustainable agricultural practices. By using 'primary questionnaire data' and 'discrete choice experiment (DCE) technique', this research reveals the choices tomato producers and consumers make and their valuation of different scenarios of cleaner tomato production in Pakistan. Fundamentally, this research aims to yield useful policy suggestions regarding the use of market-based approaches by informing tomato farmers' and tomato consumers' preferences for sustainably grown tomatoes in Pakistan.

1.2 Background

Approximately 42% of the world's population depends directly on agriculture for its livelihood, a sector that contributes significantly to the economies of most of the developing countries (Aznar-Sánchez et. al., 2019). Since the remarkable success of the 'green revolution' of the 1960s (Schutter, 2017), modern agriculture has gradually become more industrialised, favouring large scale production and employing intensive farming techniques (Muller et al., 2017; Schutter, 2017). However, this has been accompanied by a tremendous increase in food demand and production due mostly to the increase in global population, producer margins, household incomes, and international trade of agricultural commodities (Zhou et al., 2019; Rega et al., 2019).

To meet the growing food demand, farmers have increasingly relied on intensive production methods that involve greater input (water and agrochemicals) application (Sidemo-Holm et al., 2018; Zhou et al., 2019). This has caused significant environmental damage in terms of water, soil, and air pollution; biodiversity loss; and off-farm cost to human health (Mouysset et al., 2015; Lai, 2017; Zhou et al., 2019). As a result, a decline in the delivery of essential ecosystem services, such as pollination (Wilson et al., 2017), pest control (Bommarc et al., 2018), nutrient cycling and erosion control is witnessed (Wilson et al., 2017). The problem is even more serious in developing countries due to prevailing socioeconomic stressors including poverty, unemployment, food insecurity, and limited off-farm income, and this is exacerbated by heavy reliance on agriculture and poor environmental compliance (Lai, 2017; Chen et al., 2017).

Increasing food production while conserving biodiversity thus poses a massive challenge to contemporary societies (Petersen and Snapp, 2015; Saitone and Sexton, 2017; Rega et al., 2019). Hence, the goal is to reconcile agricultural land-use and farming practices with farmland biodiversity (Mouysset et al., 2015). This can facilitate a transition towards a sustainable agricultural future (Pigford et al., 2018; Alexander et al., 2019), which enables farmers to grow crops in environmentally responsible ways to avoid further deterioration of environmental quality (Mouysset et al., 2015).

The quest for a harmonious relationship between food production and the natural environment (Candiotto et al., 2018) can enhance yield while protecting the environment (Dougill et al., 2017). This has become increasingly pressing (Aznar-Sánchez et al., 2019) due to the impacts of modern agriculture on human health and the environment (Alexander et al., 2019). In this regard, sustainable agriculture is a win-win strategy (Zeweld et al., 2017) as it can reduce the cost of production by means of reducing the intensive use of agricultural inputs and increase the profit margins via the price premium on relatively cleaner produce, in addition to yielding positive health and environmental outcomes from agriculture.

From the demand-side, consumers have also been encouraged to adopt healthy lifestyles, including food choices (Allan et al., 2019; Irz et al., 2019). Therefore, due to increased levels of environmental awareness and sensitivity, consumers and policy makers have indicated concerns about food safety and demanded the adoption of food production systems that are friendly for both human health and the natural environment (Saitone and Sexton, 2017).

Thus, the adoption of sustainable agricultural practices is necessary to reduce the negative impacts of agriculture and enhance on-farm conservation (Böcker et al., 2019). However, there are certain economic benefits that often encourage unsustainable farming practices (Scherer et al., 2018). For example, farmers employ intensive farming techniques to increase the per acre yield of their crops. Compounding this problem, regulating to mitigate agricultural pollution and achieve desired environmental outcomes typically proves insufficient (Sidemo-Holm et al., 2018) as well as highly contentious (Petersen and Snapp, 2015). Hence, market-based mechanisms are increasingly being proposed as a way to restrict agricultural pollution (Petersen and Snapp, 2015; Sidemo-Holm et al., 2018) and offset the incentives in unsustainable farming practices.

Market-based mechanisms are policy instruments that use markets, price and other economic variables to provide incentives for polluters to reduce or eliminate negative environmental externalities. Market-based mechanisms are a way to reconcile environmental conservation and economic development (Mariki, 2016) and seek to address the market failure of externalities such as pollution. These mechanisms incorporate the external cost of production or consumption activities through taxes or charges on processes or products. They help create property rights and facilitate the establishment of a proxy market for the use of environmental goods and services. Market-based mechanisms for pollution control are becoming more popular both in the environmental economics literature and in real-world policymaking (Coggins and Rosato, 2002).

Market-based mechanisms are devised using the concept of economic efficiency, achieving maximum resource protection for a given level of production (Lafuite et al., 2018). Market-based mechanisms are usually considered more efficient than regulations (Van Hecken et al., 2019), and make the proposed changes in agricultural practices attractive to undertake for farmers (Ezzine-de-Blas et al., 2019). Therefore, in order for farmers to adopt sustainable agricultural practices, there is a need to design some economic incentive schemes (Capmourteres et al., 2018; Böcker et al., 2019) to use market-based mechanisms instead. However, the use of the economic incentive schemes and thus the market-based mechanisms require empirical evidence on its viability and effectiveness which could be produced using applied economics valuation research.

The present research also uses the idea of market-based mechanisms, i.e. economic incentive schemes, to implement sustainable agricultural practices in the Pakistani context. Here, sustainable agriculture refers to a set of changes in existing agricultural practices used in tomato cultivation in district Khushab of Punjab, Pakistan. These changes include the reduction in the use of agrochemicals and adoption of efficient irrigation technologies. The analysis is carried out using questionnaire data and discrete choice experiment (DCE) approach. Questionnaire data are used to investigate farmer and consumer perceptions of different farming practices, whereas DCEs are used to uncover farmer and consumer preferences and their valuation of the reduction in the use of agrochemicals (pesticides and fertilisers) and adoption of efficient irrigation technologies (furrow and drip irrigation) in tomato crop production.

The analysis elicits consumer willingness to pay (WTP) a price premium and farmer willingness to accept (WTA) the compensations to introduce the changes to the tomato production crop. Using the WTP and WTA estimates, this study proposes to design economic incentive schemes to reduce intensive farming and make food production safer, and that is how market-based mechanisms could help implement the sustainable agricultural practices in the context of present research. Since consumer WTP will be used to compensate the farmers, the market itself offers a solution to the problem of agricultural pollution in tomato cultivation. This could incentivise the uptake of sustainable agricultural practices which would be a significant step towards the design of policies using market-based mechanisms rather than regulations in Pakistan.

1.3 Study context

The present research examines agricultural practices being employed in Pakistan. More specifically, it investigates citizens' perceptions and preferences with regards to tomato farming in one of the districts of the Punjab Province.

a. Agricultural practices in Pakistan

Agriculture plays a key role in the Pakistani economy as it makes up almost 18.5% of GDP (GoP, 2019). It is a source of livelihood for a vast rural population as it employs approximately 38.5% of the labor force, mostly low-skilled, which is significant considering the paucity of off-farm income opportunities in rural areas of Pakistan. The total cultivated area of Pakistan is 23.6 million hectares, of which 18.64 million hectares is irrigated (GoP, 2019). The main crops include wheat, maize, rice, sugarcane, and cotton; with secondary crops being pearl millet (bajra), sorghum (jowar), barley, pulses such as red lentil (masoor), black lentil (mash), green gram (moong), rapeseed, mustard, and vegetables.

However, Pakistani agriculture, as currently practiced, is generally unsustainable due to the degradation of agricultural resources (Zulfiqar and Thapa, 2017). Furthermore, the heavy reliance on agriculture in terms of food, fodder, and livelihood is also a factor that contributes to the use of intensive farming. Intensive farming in Pakistan involves the concentrated use of agricultural inputs, such as agrochemicals and irrigation water, which are damaging to human health and the natural environment (Abedullah et al., 2015). For example, the use of agrochemicals results in soil and water pollution in addition to having a negative impact on aquatic life (Quaglia et al., 2019). The overuse of agrochemicals in Pakistan can be attributed to a combination of a lack of user knowledge concerning recommended dosages, poor training, and poor enforcement of relevant regulations (Tariq et al., 2007; Azizullah et al., 2011; Saeed et al., 2017).

There is strong evidence of the presence of agrochemical residue in Pakistani water (Tariq et al., 2007; Azizullah et al., 2011; Waseem et al., 2014). For example, research shows the presence of pesticides like monocrotophos (40 to 60 µg/L), cyhalothrin (traces to 0.2 µg/L), and endrine (0. 1 to 0.2 µg/L) in the groundwater of Faisalabad, in addition to Multan, Mardan and Swabi where samples exceeded the maximum acceptance concentration (MAC) and maximum residual limits (MRLs) (Azizullah et al., 2011). Research further shows that organochlorine pesticides ranged between 66 and 530 pg/g in soil, 5 and 13 pg/L in surface water, and 14 and 191 pg/m3 in air, respectively (Ullah et al., 2019).

Likewise, Ahmad et al.'s (2019) study on soil analysis revealed that concentration of α- and β-endosulfan ranged from 0–14 to 0–14.64 µg/mg, respectively. In addition, the blood samples of people involved in agriculture showed mean concentrations of 1.13, 0.92, 0.68 and 1.96 ngmL−1 for pp-DDT, aldrin, dieldrin, and endosulfan, respectively, while those living away from agricultural fields have mean concentrations of 0.30, 0.19, 0.14 and 0.41 ngmL−1 for pp-DDT, aldrin, dieldrin, and endosulfan, respectively (Saeed et al., 2017). Research by Shahid et al. (2016), claim that over 500,000 Pakistanis suffered annually from poisoning due to agrochemicals, out of which 10,000 died. Hence, there are serious health and environmental concerns regarding current farming practices in Pakistan (Abedullah et al., 2015; Zulfiqar and Thapa, 2017). It is against this background that the present research proposes modifications in existing agricultural practices to make it sustainable. This analysis is a case study of tomato cultivation in Khushab, Pakistan.

b. Study site

Khushab is located in the Punjab Province of Pakistan, situated between the Indus River and the Jhelum River and covers agricultural lowland plains. Like all other places, agriculture in Khushab is also based on intensive farming. There are multiple factors responsible for intensive farming in Khushab, for example, lack of technical capacity and outreach of agricultural extension services and a de-facto role of agrochemical companies which advise farmers to adopt intensive production methods. Other factors which contribute to the use of intensive farming and impede the adoption of sustainable agriculture include low farmer literacy and education and farm households' financial constraints.

c. Tomato cultivation

Tomatoes in Khushab are grown on a commercial scale using an irrigated farming system. Tomato cultivation is not fully mechanised as ploughing is done with tractors and remaining work is carried out manually. For example, the furrow irrigation method is commonly used to irrigate the tomato crop. Tomato crop is produced seasonally along with other vegetables such as onion and cereal crops which mainly include corn and wheat. Tomatoes are cultivated by the farm owners as well as tenants using contract farming by negotiating pre-sowing contracts with owners. Culturally, women and children also participate in farming operations such as nursery raising, transplanting, weeding, harvesting and cutting as employing family labour in agriculture is very common in rural areas of Pakistan.

Tomatoes in Khushab are grown using intensive farming techniques, i.e. concentrated use of irrigation water and agrochemicals[1]. The tomato cultivation in Khushab as well as the farming practices used in this crop are determined by a number of factors. For example, Khushab has fertile land, good climate, market connections, and conditions conducive to tomato cultivation. The suitable soil for tomato cultivation in Pakistan is clay loam, sandy loam, sandy clay loam, loam, and silt loam in addition to a warm climate, which Khushab offers. Similarly, the concentrated use of agricultural inputs in tomato cultivation has a clear incentive for farmers as it increases crop yield per acre, and hence the revenue. However, farmers often complain about the increased input costs as inputs such as agrochemicals and tomato crop seeds are imported, and hence are very expensive for farmers. While tomato is a cash crop and farmers grow tomatoes to earn their livelihood, they are often unhappy about the relatively low farm gate price of tomatoes, but they continue to grow tomatoes as there is a paucity of off-farm income opportunities and limited options of commercial crops.

Farmers in Khushab face a trade-off between grain and tomato crops and the decision to allocate the land is made considering the crops' revenue and households' own food requirement. For example, tomato cultivation is an important vegetable crop in Khushab as it yields significant net revenues. Furthermore, tomato crop requires significantly less land than the grain crops as a small part of farmland could be used for tomato cultivation at commercial scale. Due to domestic market demand, unfavourable climatic changes, and poor infrastructure; tomatoes produced in Khushab are not exported. Instead they are sold in local markets such as Islamabad and Lahore. The domestic supply chains are however relatively better as tomatoes are supplied in the main vegetable markets through the procurement agents and all the shopkeepers purchase the produce from wholesalers.

Tomato crop is chosen for this research because it is a cash crop and a commonly used vegetable in Pakistani households. Similarly, the supply chain and price structure of tomato crop is relatively easy to track and understand, which is crucial to design a discrete choice experiment (DCE) study. Furthermore, as tomatoes are consumed directly as salad as well, consumers are expected to be more responsive to the proposed changes presented to them.

d. Proposed changes

Since tomatoes are produced using intensive farming that entails the concentrated use of agricultural inputs, including water and agrochemicals, agricultural pollution is a rampant problem in Pakistan. The intensive farming deployed to produce tomatoes has serious implications for human health and the natural environment. For example, it was revealed during the survey that tomato farmers use up to

[1] The current as well as the recommended use of agrochemicals in tomato cultivation is given in Table 2.5 in Chapter 2 under the heading of '2.4.2 Collected background information'.

five types of pesticides and they apply those as per advice of the pesticide companies' sales representatives who advocate for the greater use of their products. Hence, the present research proposes changes in existing agricultural practices. The modifications that the present research proposes in existing agricultural practices include reduction in fertilisers use by one third (33%) and a half (50%), reduction in pesticides use by one third (33%) and one fourth (25%), and adoption of furrow and drip irrigation which, compared to flood irrigation method, saves the irrigation water.

1.4 Significance

Tomato farmers in Khushab employ intensive farming methods that lead to the deterioration of environmental quality and human health as the concentrated use of agrochemicals causes food contamination as well as environmental pollution. This research is an investigation of farmer and consumer perceptions and preferences regarding the modification in current agricultural practices used in tomato cultivation in Khushab Pakistan. This work is fundamentally *applied* research, with its essential objective being to use the DCE and the questionnaire data to produce empirical evidence on the farmer and consumer perceptions and preferences. Hence, the goal of this research is to generate policy suggestions for the uptake of the proposed changes, and hence the sustainable agricultural practices to produce cleaner tomatoes.

Questionnaire data is used to investigate tomato farmer and consumer perceptions with regards to different farming practices. Understanding tomato farmer and consumer perceptions is very crucial to design policies for the uptake of sustainable agricultural production for tomato cultivation in Pakistan. Analysis reveals the factors that can drive the uptake of sustainable agricultural practices and thus cleaner tomato production, which can help in designing more targeted interventions to facilitate a transition towards sustainable farming in Pakistani agriculture. DCE is employed to study tomato farmer and consumer preferences for the modification in current agricultural practices used in tomato cultivation in Khushab.

Since DCE offers valuable insights regarding the importance of different policies' features or their contribution to citizens' welfare, the monetary valuation of the proposed changes in existing agricultural practices used in tomato cultivation reveal the value that consumers place on different scenarios of sustainable agriculture and compensations that farmers demand to adopt some of those. This could guide policy makers about the economic benefits of the proposed changes in existing agricultural practices and the uptake of sustainable agriculture in tomato cultivation. Benefit-cost analyses of different projects regarding cleaner food production in Pakistan could also be conducted using these results. Furthermore, considering the Pakistani government's resource constraints, DCE can inform important policy decisions regarding the allocation of scarce resources for food and agricultural policies. Since this research uses the DCE approach in low-income, low-literacy rural settings in a developing country, it also reveals the usefulness of this state-of-the-art methodological tool in a unique context. Moreover, it is hoped that the application of DCE in this research can also inform the use of the methodology in similar contexts within and outside Pakistan, thus helping to refine this powerful tool.

Welfare estimates (e.g. WTP and WTA) from DCEs' could be used in the design of economic incentive schemes to modify existing agricultural practices used in tomato cultivation. Such schemes, it is hoped, could be used as a tool to mitigate some of the agricultural pollution affecting Pakistan today. The use of economic incentive schemes is a market-based mechanism to implement the proposed changes in existing agricultural practices to ensure health- and environment-friendly cleaner food production. This might not otherwise be possible due to the insufficient monitoring, compliance and enforcement of traditional regulatory methods, as highlighted above.

Besides the concentrated use of agrochemicals in agricultural practices, food adulteration is another serious problem in Pakistan. Electronic and printed media frequently reports on incidents of food adulteration and violation of health and safety regulations in food production, processing and sale. However, due to a lack of government resources, there is insufficient monitoring, enforcement and environmental compliance in the food industry. Thus, it is vital to investigate the alternative approaches, e.g. market-based mechanism, to make cleaner food production and supply possible, and it is hoped that the present research can pave the way to investigate such issues as well.

Another important issue that this research deals with is that the tomato farmers in Khushab Pakistan face high production costs due to expensive imported seeds and agrochemicals and increasing labour costs. Yet they receive low farm gate prices for their produce due to high seasonal fluctuations in supply and demand and role of the middlemen. This phenomenon presents a serious challenge to the livelihood of the tomato farming community in Khushab. For example, often the farm gate price of tomatoes is so low that farmers prefer to abandon the harvest, as after adjusting the harvesting cost, they return either very low or no profit. In this situation, the present research could possibly help tomato farmers in two ways: first, the proposed changes can reduce production costs by reducing the use of agrochemicals; and second, the adoption of proposed changes can improve farm gate prices of tomatoes by offering a price premium for relatively cleaner food production.

Overall, this analysis will highlight the potential for sustainably grown tomatoes to attract consumer interests and the kind of incentives which could work for farmers to produce those.

1.5 Research questions

The objectives of this research translate to a set of specific research questions, as follows:

1. What are farmer and consumer perceptions of the existing agricultural practices used in tomato crop and the proposed changes to adopt sustainable agriculture?
2. What are the factors that explain farmer and consumer perceptions of existing agricultural practices and proposed changes?
3. What are farmer preferences and WTA's for the reduction in the use of pesticides and fertilisers and adoption of efficient irrigation technologies in the tomato crop?
4. What are consumer preferences and WTP's for the reduction in the use of pesticides and fertilisers and adoption of efficient irrigation technologies in the tomato crop?
5. How could the DCE inform policy makers to design economic incentive schemes as a market-based mechanism for the modification in existing agricultural practices used in tomato crop?

1.6 Research gaps

Research in the field of economic valuation has dramatically increased, resulting in a multitude of studies investigating the use of market-based approaches in policy design. For instance, McFadden (1994), Hanley et al. (1996), Hanley et al. (1998), Buckland et al. (1999), Louviere et al. (2000), Hanley et al. (2001), Bateman et al. (2002), McFadden (2017), McFadden and Train (2017), and Hanley and Czajkowski (2019) are some of the main pieces of valuation research. Recently, use of the discrete choice experiment (DCE) approach as a valuation tool has become popular in economic valuation research in several fields, including environmental economics. Some of the important contributions in DCE research include Hensher et al. (1981), Hanley et al. (1998a), Hanley et al. (1998b), McFadden and Train (2000), Hanley et al. (2001), Hensher et al. (2005), and Scarpa et al. (2008).

However, the bulk of DCE studies have been conducted in the developed world (Mangham et al., 2009). As a result, the use of DCE for economic valuation, and hence the market-based mechanisms to design policies, is relatively less in some of the developing countries. For example, only three DCE studies (Kouser and Qaim, 2013; Bell et al., 2014; and Burton et al., 2020) were found from Pakistan. This means that there might not be sufficient valuation research, and hence the empirical evidence on the use of market-based approaches in Pakistan which is a gap in literature. Conducting valuation research using DCE however could inform the policy making process on what improves citizens' welfare. The present research seeks to fill this lacuna in the Pakistani context.

More specifically, this work targets the following:

1. Current agricultural practices used in Pakistan are based on intensive farming which are harmful for human health and the natural environment. In this regard, there is no study on citizens' perceptions of current agricultural practices which could guide how citizens see these practices and if there are any changes that they want. The present research fills this gap by investigating

the farmer and consumer perceptions of existing farming practices and proposed changes in tomato crop in Khushab, Pakistan.

2. Due to a dearth of valuation research in Pakistani agriculture, there is no empirical evidence on farmer and consumer preferences for different agricultural practices to guide policy makers in their design of food and agricultural policies. The present research fills this gap in literature by conducting two DCEs which investigate farmer and consumer preferences for proposed changes in current agricultural practices used in tomato cultivation in Khushab to make tomato farming sustainable.
3. Health- and environmental- friendly food production is an important area in food and agricultural policy. However, since policy makers in Pakistan do not have first hand information about the value that people place on health and environmental attributes of food production in Pakistan, it is difficult for them to make resource allocation decisions. Monetary valuation of the health and environmental attributes in this research could furnish actionable information to policy makers to make informed decisions regarding resource allocation for cleaner food production and sustainable agriculture.
4. Use of economic incentive schemes and market-based mechanisms, instead of regulations, is barely present in food and agricultural policies of Pakistan. It is safe to assume that this is mainly due to the limited empirical evidence on the effectiveness of market-based approaches. This study seeks to remove this impediment to policy design by highlighting the possible use of economic incentive schemes to modify existing agricultural practices and improve the enforcement and compliance of food quality standards.
5. Literature search has revealed that there is no research in Pakistan which could inform farmers, food businesses and other stakeholders about the consumer willingness to pay a price premium on cleaner produce. However, this information is crucial for them to engage in cleaner food production and sale and make investment decisions. This study addresses this issue by revealing useful information regarding consumer WTP and farmer WTA for cleaner tomato production, which might be helpful to assess the potential of cleaner food production in Pakistan.

1.7 Research contributions

This section outlines the main contributions of the present research, which seeks to: 1) investigate farmer and consumer perceptions and preferences for the modification of existing agricultural practices; 2) estimate the monetary value of the proposed changes; 3) design and implement two DCEs in a low-income low literacy setting; 4) and offer empirical evidence on the price premium, which farmers are willing to accept and consumers are willing to pay to encourage the production of relatively cleaner tomatoes and adoption of sustainable agriculture using market-based mechanisms.

The aim of this research is to give policy suggestions in the light of empirical evidence rather than to inform methodology and/or theory. Hence, the contribution of the present research should be seen in the context of policy design, as well as bridging a gap in literature, rather than the development of methodology itself. The specific contributions of this research are outlined below:

1. Previous research on citizens' preferences for sustainable agriculture has mostly focused on either demand or supply side; however, the present research covers both aspects of sustainable agriculture. This allows collating and comparing the farmer and consumer preferences and their monetary valuation of the proposed changes required in existing agriculture practices used in tomato cultivation to make it sustainable. For example, by uncovering the price premium that farmers demand and consumers are willing to pay on sustainably grown tomatoes, this research gives a clearer picture of the scope of cleaner tomato production, and hence the uptake of sustainable agriculture in study areas.
2. This research uses the actual supply chain of the tomatoes produced in district Khushab (farmer survey site) to investigate farmer and consumer preferences for the modifications in existing agriculture practices. As tomatoes cultivated in Khushab are sold in Islamabad (consumer survey site), this connects tomato producers and consumers. This makes the findings of this research more realistic and practical as they offer area- and crop-specific information which is a concrete input for policy makers to design economic incentives to encourage the uptake of sustainable agriculture and cleaner food production.
3. Previous studies have mostly investigated the changes in existing agricultural practices; however, this research also includes inspection of the proposed changes as a credence attribute in the consumer survey. This is to assure farmer compliance with the proposed changes as cleaner produce could be labelled if there is a satisfactory compliance, and labels will help consumers to identify the cleaner produce in the market. The credence attribute uncovers the value consumers place on farmer compliance with the proposed changes in existing farming practices.
4. Past studies have frequently investigated agrochemical use in the context of sustainable agriculture which is very narrow as sustainable agriculture seeks to reduce the concentrated use of various agricultural inputs including irrigation water. Hence, the present research also investigates the improvement in irrigation methods for the uptake of sustainable agriculture. Similarly, prior research has predominantly focused on pesticide use reductions, but this research considers the reduction in the use of fertilisers as well.
5. In contrast to past research which has examined farmer and consumer perceptions, this research not only deploys a coupled approach to compare the farmer and consumer perceptions, but the empirical analysis of the factors affecting farmer and consumer perceptions is also informed by

the heterogeneity in farmer and consumer perceptions which was uncovered in descriptive analysis and warranted for further investigation.

6. Previous research has mostly investigated the improvements in some of the aspects of cleaner food production where it is already being used at large scale. This research however is unique in this respect as it investigates cleaner food production in a market where the demand for cleaner food exists but the production is insignificant. For example, cleaner food options such as organic vegetables are not available in ordinary markets. Hence, this research seeks to contribute towards the development of the cleaner food production market, which is an under-developed sector in Pakistan.

1.8 Thesis outline

This dissertation comprises seven chapters. Chapter 1 is the introduction, which provides the reader with the background to frame the research problem and explain the motivation to conduct this research. This chapter also highlights the context and significance of this study and outlines some of the key research questions based on the problem statement. The chapter also discusses the research gaps and key contributions of this research.

Chapter 2 discusses the research context and survey design. Specifically, this chapter explains the Pakistani agricultural systems and the background work that has been done to design the surveys of the present research.

Chapter 3 presents a detailed description of the DCE methodology used in this research in chapter 4 and 5. This includes a detailed discussion on the DCE theoretical framework, the model specifications in preference as well as price-space, the design and the implementation of the DCEs including the data collection and analysis in this research. Nevertheless, a brief description of methodology is provided in chapter 4 and 5 as well. As this PhD thesis takes the form of three papers; the following chapters 3, 4 and 5 present each one of the three papers.

Chapter 4 investigates farmer and consumer perceptions of existing farming practices and proposes to adopt sustainable agricultural practices. This research is conducted using the questionnaires data and probit regression technique, and it provides a background to the two DCE studies presented in chapter 4 and 5.

Chapter 5 is a DCE study to investigate farmer preferences for sustainable agricultural practices. This research investigates farmer willingness to adopt health- and environment-friendly tomato production practices in the Pakistani context. The analysis is conducted using a primary survey that involves the face-to-face interviews of tomato farmers from the Khushab district of Pakistan.

Chapter 6 is similar to Chapter 4; however, it is a study of consumer preferences for sustainable agricultural practices instead. Hence, this investigates the health- and environment-friendly tomato production practices from the demand side. This is also a DCE approach-based analysis, which is conducted using a primary survey of consumers from Islamabad, the capital of Pakistan. The introduction of this chapter might demonstrate some resemblance to the introduction to chapter 4, the intent is to enable the reader to read each of the studies in isolation and still grasp the full context within which they have been conducted.

Chapter 7 discusses the overall conclusion and policy implications of this research. It provides a summary of the research findings, draws lessons from the results and presents the key policy implications from this study. Furthermore, it also outlines some of the main limitations of this research, in addition to the future research dimensions and lessons for future research.

The next chapter (Chapter 2) details research context and survey design.

Chapter 2 Research context and survey design

2.1 Background

The present research is an investigation of the existing agricultural practices and proposed changes to adopt sustainable agriculture for tomato cultivation in one of the districts in Punjab, Pakistan. It proposes to reduce the use of agrochemicals and adopt efficient irrigation technologies to produce cleaner tomatoes. This chapter documents the research context, process and the material used in the development of the research questions. The objective of this chapter is to provide sufficient information to the readers to understand the background and motivation of this research. The discussion shows how and why the adoption of sustainable agriculture is relevant in the context of present research.

This discussion includes the description of the Pakistani agricultural system, crop of interest, study area, and supply chain, the link between production and consumption of tomatoes which is the crop of interest in this study. It also provides details about the background information such as sources of information and how the gathered data and information has informed the design of this research. For example, the collected data and information helped in developing the survey instrument and designing both pilot surveys conducted for this research. This chapter also presents a brief description of pilot surveys at the end.

The next section describes the Pakistani agriculture system.

2.2 Pakistani agricultural system

Agriculture sector has an important role in the Pakistani economy as it employs approximately 38.5% of the labor force and has a contribution of 18.5% in the GDP of the country (GoP, 2019). According to the 2017 Population and Housing Census of Pakistan, 63.6% of the country's population still resides in rural areas; most of which relies on agriculture for food, fodder, and livelihood. The main sub-sectors of agriculture sector in Pakistan are food and fibre crops and horticulture, livestock and dairy, fisheries, and forestry. There are more than five million farms in the country, 81 percent of these are less than five hectares and roughly seven percent are over 20 hectares (FAO, 2004).

Pakistan has two crop seasons namely Kharif and Rabi. Kharif sowing begins in April and harvest is between October and December and Rabi begins in October to December and ends in April to May. The major crops include wheat, maize, rice, sugarcane, and cotton; with minor crops being pearl millet (bajra), sorghum (jowar), barley, pulses such as red lentil (masoor), black lentil (mash), green gram (moong), rapeseed, mustard, and vegetables.

According to the Economic Survey of Pakistan 2019-20, the production of some of the major crops is such that rice production stands at 7.410 million tonnes, production of maize is 7.236 million tonnes, cotton production is 9.178 million bales, sugarcane production is 66.880 million tonnes and wheat production is 24.946 million tonnes (GoP, 2020). The major crops such as wheat, rice, sugarcane, maize, and cotton account for 21.73 percent and other crops account for 11.53 in the value addition of agriculture sector. Moreover, wheat, rice, sugarcane, maize, and cotton are 4.20 percent in GDP and the remaining crops are 2.23 percent in GDP (GoP, 2020).

Livestock, fishing and forestry also contribute to Pakistani agriculture, for example, livestock has a 60.56 percent share in the agriculture sector while contribution of the sector in GDP is 11.69. It is important to mention here that livestock has emerged as the largest sub-sector in Pakistani agriculture as it contributes almost 3.1 percent in total exports and estimates show that more than 8 million rural farm households are engaged in livestock production and derive more than 35 to 40 percent of their income from livestock. Fishing sector contributes 2.06 percent in agricultural value addition and 0.40 percent in GDP. Likewise, the forestry sector has 2.13 percent share in agriculture and 0.41 percent in GDP (GoP, 2020).

Table 2.1: Overall farm size in Pakistan

Farm size (Acres)	**No. of farms**		**Farm area (Acres)**		**Cultivated area (Acres)**	
	Total	**Percent**	**Total**	**Percent**	**Total**	**Percent**
Total	**8264517**	**100**	**52910400**	**100**	**42622497**	**100**
Under 1.0	1254718	15	527120	1	465890	1
1.0 to under 2.5	2342233	28	3647770	7	3398611	8
2.5 to under 5.0	1753995	21	6009162	11	5602479	13
5.0 to under 7.5	1131990	14	6493940	12	6045054	14
7.5 to under 12.5	917007	11	8747731	17	7979521	18
12.5 to under 25.0	560748	7	9361207	18	8270124	20
25.0 to under 50.0	210907	3	6725882	13	5387577	13
50.0 to under 100.0	66874	1	4146547	8	2997541	7
100.0 to under 150.0	12607	0.2	1401098	3	942081	2
150.0 and above	13438	0.2	5849943	11	1533619	4

Source: Pakistan Agriculture Census 2010

Table 2.1 shows the farm size distribution in Pakistani agriculture which is skewed as roughly 64 percent farms are less than 5 hectares and there are a few very large holdings. In addition, most of the small farms are jointly owned, and the ownership rights have not been granted to the individual owners. This old land titling system discourages efficient land markets, investment in land, and the use of land as collateral to seek formal credit. Furthermore, this has significant negative implications where the land is fragmented.

The Pakistani agricultural system is very diverse as there are ten agro-ecological zones in Pakistan and each zone is unique with respect to soil topography, climate, farming practices and crops. Moreover, farming systems depend on the land types, micro-climate, availability of irrigation water, market access, population density, transport infrastructure and cultural aspects (FAO, 2004). Roughly 70 percent of the total rainfall occurs in summer between the months of July and September, and the remaining 30 percent occurs in winter (FAO, 2004), although recently there have been changes in the average weather pattern. There are fifteen crop production regions (CPRs) in Pakistan, grouped according to their major cropping patterns (FAO, 2004).

Pakistan has three hydrological units. First, the Indus basin that covers the whole of the provinces of Punjab, Sindh, Khyber Pakhtunkhwa, and the eastern part of Balochistan. Second, the Kharan desert in the west of Balochistan which is an endorheic basin covering 15 percent of the territory. Third, the arid Makran coast along the Arabian Sea covering 14 percent of the territory in its southwestern part which is the Balochistan province (FAO, 2004). The study areas of the present research are situated in the Indus basin.

Country is situated in the 4000-year-old Indus civilization and has the largest irrigated area in the world in the form of the Indus Basin Irrigation System. The annual influx of the Indus River has about 180 billion cubic meters of water which mainly comes from the Himalayan snow melt shared with neighbouring countries. The total cultivated area of Pakistan is 23.6 million hectares, of which 18.64 million hectares is irrigated (GoP, 2019), while the remaining is under dry farming. Roughly, 85 percent of the crop area in Pakistan is irrigated by canals. The major sources of irrigation in Pakistan are rivers, streams, springs (surface), dug-wells and tube-wells (sub-surface). River water is channelled through dams, barrages, and headworks into major and minor canals, and then to farm ditches through watercourses.

Government canals are roughly 6.38 million hectares (58 percent in the Punjab and 29 percent in the Sindh province), whereas private canals are 0.43 million hectares and 81 percent of these are in Khyber Pakhtunkhwa. On the other hand, the share of tube-wells in irrigation is 3.45 million hectares and 82 percent of these are in Punjab. Furthermore, there are open wells which are 0.2 million hectares and 55 percent are in Punjab. Canals and tube wells are 7.24 million hectares and all of them are in Punjab. The other means of irrigation are 0.18 million hectares (FAO, 2004). The total availability of water for the Kharif crops in 2019 was 65.2 million-acre feet (MAF), whereas total availability of water for the Rabi crops in 2019 was 29.2 MAF (GoP, 2020). Canal water withdrawal during Kharif (April-September) 2019 was 65.23 MAF and during Rabi (October-March) 2019-20, it is 29.20 MAF (GoP, 2020).

However, Pakistan is a water stressed country and there is an acute water shortage in the country. It used to have sufficient groundwater reserves which are threatened by salinization and water-logging caused by intensive irrigation and unsustainable management of water resources. This, as a result, has caused water shortage in the agriculture sector in Punjab and Sindh, which are two of the provinces of Pakistan where there is irrigated agriculture. There is an urgent need to upgrade the aging irrigation infrastructure and adopt new technologies such as sprinkle and drip irrigation to efficiently use the shrinking water resources. Another problem with the Pakistani irrigation system is that water productivity in Pakistan is very low which means that crop outputs per hectare and per cubic meter of water are much lower than international benchmarks. Since irrigation also depends on rainfall, it is important to highlight the rainfall information. Data shows that while during the 2019 monsoon season (July and September) 140.4 mm rainfall was received, 56.3 mm rainfall was recorded in the post-monsoon season (October-December) 2019. Similarly, during the winter season (January-March) 2020 the recorded rainfall was 123.0 mm.

As explained in Chapter 1, agriculture in Pakistan is mostly based on intensive farming which involves the concentrated use of inputs such as agrochemicals and irrigation water. Agrochemicals mainly include fertilisers and pesticides. Use of pesticides is relatively new in Pakistan, however, fertiliser use dates back to the 1950s and 1960s. For example, nitrogenous fertilisers were introduced in Pakistan in 1952 followed by phosphorus in 1959/60, and then potassium in 1966/67. However, fertiliser use gained momentum in the 1970s, when high yielding varieties of cereal crops were introduced. Fertiliser data shows that the share of the private sector in fertiliser marketing and sale is 89 percent, compared to 11 percent of the public sector. Furthermore, the private sector handles about 90 percent of the supply of the urea and 100 percent of the DAP (diammonium phosphate), which are the two main fertilisers used in the country (FAO, 2004).

Table 2.2: Fertilisers (Urea and DAP) availability

	Rabi (Oct-Mar) 2019-20		Kharif (Apr-Sep) 2020*	
	Urea	**DAP**	**Urea**	**DAP**
Opening stock	470	406	580	487
Import	0	849	0	87
Domestic production	2994	324	2823	420
Total availability	3464	1579	3403	994

Source: Economic Survey of Pakistan 2019-20

Price of Urea and DAP, the most widely used fertilisers in Pakistan and produced by private companies, is largely unregulated. Economic Survey of Pakistan 2019-20 revealed that 52 percent of fertiliser is used in Rabi season while 48 percent in Kharif season. Since Urea and DAP are used more frequently in Pakistani agriculture, these fertilisers are imported as well as produced locally. The details of the local production and import of fertilisers in Pakistan is given in Table 2.2.

The use of pesticides in Pakistan is relatively new than fertilisers, but recently it has become very popular. Table 2.3 presents the data on pesticides used in Pakistani agriculture, however, it only gives an overview as due to a lack of complete data, this does not provide complete information of the pesticide types and their usage in different crops. It is important to mention here that there is an overuse of most of the pesticides in Pakistani agriculture, which is due to unregulated sale and purchase of pesticides. Furthermore, instead of following the agricultural extension guidelines to use pesticides, farmers rely on the information provided by the pesticide companies as it is readily available.

Table 2.3: Pesticide consumption

Type	**Quantity (M.T)**
Production	8848
Import	57402
Total	66250
Value	12600 million rupees

Source: Agricultural Statistics of Pakistan 2013-14

However, the overuse of pesticides has serious consequences. For example, Persistent Organic Pollutants (POPs) which are used in pesticides are highly toxic chemicals considered as a global threat to human health and the environment. Since Pakistani agriculture is based on intensive farming, a range of environmental problems are associated with it. Contamination of underground fresh water by leaching of nitrites due to concentrated use of agrochemicals such as nitrogenous fertilisers, indiscriminate use of pesticides and contamination of produce with toxic pesticide residues, over extraction of underground water, and the disposal of industrial toxic waste into canals are some of the main issues related to crop intensification.

Pakistani agriculture is mostly less mechanised as some of the agricultural practices of the 1960s and 1970s are still being used. For example, seeds plantation, fertiliser application, crop harvesting, and maize shelling is still being done manually. Furthermore, wheat and rice threshers are also fed manually and only few crops such as irrigated wheat and rice are harvested using machines. Similarly, isc ploughs are still common in Pakistan. In addition, efficiency, performance, and occupational health and safety are seldom considered during farming practices. Due to lack of modernization and efficiency, the average yield of the crops is lower than crop yield elsewhere in the region. Although the gap has narrowed over time, it is still much lower than the potential.

The supply of and access to factors of production, particularly timely availability of inputs, e.g. seeds at affordable cost, and machinery and equipment to small and marginalized farmers is a serious constraint to crop productivity in many of the rural areas. These issues are even more serious in the hilly areas of Northern Pakistan. Similarly, adoption of efficient irrigation methods and equitable distribution of canal irrigation is also a problem for small farmers.

The next section explains the study area, crop of interest and supply chain.

2.3 Study areas, crop of interest and supply chain

2.3.1 Study areas

The present research is conducted in Pakistan using two primary surveys, one was administered to the tomato farmers in Khushab and the other was conducted with the tomato consumers in Islamabad. Both study sites of this research are located in the Northern part of Pakistan (encircled on the Map 1). Khushab is a district in the Punjab Province of Pakistan which was established on July 1, 1982. The word Khushab is derived from two Persian words, 'Khush' and 'Aab'. Khush means pleasant and Aab means water. Khushab is a unique district of Pakistan as it has agricultural lowland plains, lakes, hills, forest, deserts, lush green harvesting land, and rivers. It is situated between the cities of Sargodha and Mianwali, near the Jhelum River with an area of 6,511 square kilometres. The administrative capital of Khushab is Jauharabad.

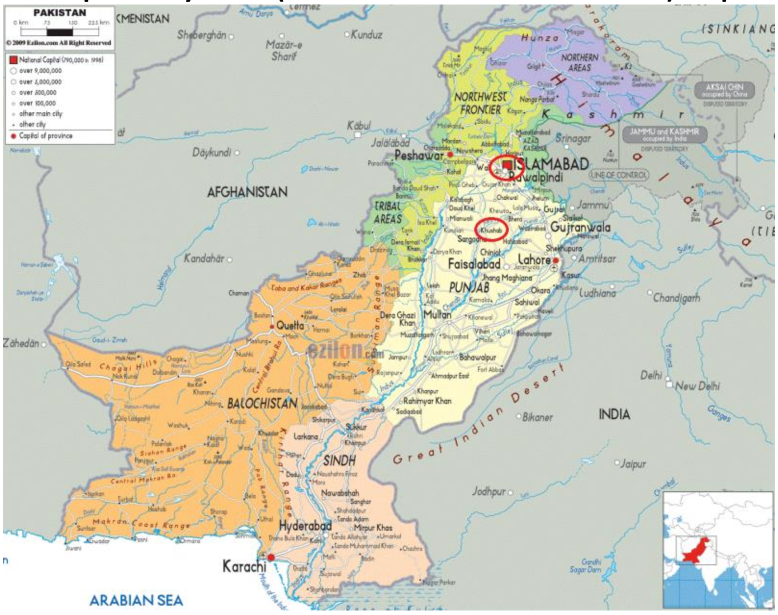
The distribution of land cover of Khushab, according to Land Cover Atlas of Pakistan, is such that district has 15.42 square kilometres orchards, 4,235.85 square kilometres irrigated crops, 41.69 square kilometres marginal and saline crops, 285.15 square kilometres crops in flood plains, 61.95 square kilometres forests, 188.77 square kilometres natural vegetation wet areas, 49.90 square kilometres range lands, 132.72 square kilometres is built up areas, 2.32 square kilometres is bare areas, 1,014.69 square kilometres is bare areas with sparse natural vegetation, and 153.68 square kilometres are wet areas.

The main crops of Khushab are sugarcane, gram, wheat, rice, ground nut and main vegetables are tomato and carrot. Most of the farms in Khushab are commercial operations, although the district has a share in small scale subsistence farming as well. The common fruits of Khushab are citrus, guavas, and bananas. Farm households also hold livestock such as cattle, buffaloes, sheep, and goats which contribute to the agriculture as well as the rural economy of Khushab. The district is also known for mineral extraction, for example, coal, bauxite, fire clay, silica sand, gypsum and rock salt which are commercially excavated in Khushab. Although cotton and jute are grown at a small scale in Khushab, there are four cotton textile/spinning mills and three jute mills operating in the district.

The total population of Khushab district, according to the 2017 Census of Pakistan, is 1,281,299, and the number of households is 211,686. The primary survey of present research was administered in two locations: Jabba and Katha Sagral. The population of Jabba, according to the 2017 Census, is 6,348 and number of households is 1102, while Katha Sagral's population is 78,351 and the number of households is 14096. Since Khushab is mostly rural, the majority of the population is involved in agriculture.

Khushab has diverse terrain and fertile land in the Punjab province of Pakistan. It has a good climate, market connections and conditions conducive to vegetable production. Khushab was chosen for this survey as the tomato crop in this district is grown on a commercial scale. Furthermore, tomatoes in Khushab are cultivated using intensive farming practices, i.e. concentrated use of agricultural inputs such as irrigation water and agrochemicals, which is the focus of this research. Tomato crop is one of the main sources of farm households' livelihood in the study area.

Map 1 Study areas (district Khushab and Islamabad) map



The consumer survey on the other hand was carried out in Islamabad, the capital of Pakistan. Islamabad is located on the Pothohar Plateau of the Punjab region. The city was built as a planned city in the 1960s and is known for its better standard of living, safety, and cleanliness unlike many other Asian cities. Islamabad is also noted for its high cost of living and its population is dominated by people from middle and upper-middle income classes. The city attracts people from all over the country which makes it one of the most cosmopolitan and urbanised cities of Pakistan. Since Islamabad is a home to people from various regions of Pakistan, it is also one of the culturally diverse cities.

The city has the highest literacy rate in Pakistan owing to relatively good educational infrastructure and improved living standard. Islamabad also has the best health facilities in the country which include both public and private hospitals. The city has become a major business and commerce centre as it has attracted highly skilled workforce from other major cities of Pakistan including Karachi, Lahore and Quetta. Islamabad also serves as a base camp for the people who come from the south and coastal areas to visit Northern Pakistan. The city has the largest expatriate population in Pakistan as all the country's diplomatic ties are maintained and exercised from Islamabad, not to mention the major embassies, consulates and missions operate from Islamabad.

The total population of Islamabad, according to the 2017 Census of Pakistan, is 2,001,579 and the number of households is 335,408. Since the primary survey for this research was administered in urban areas, the population of urban Islamabad is 1,009,832 and the number of households is 169,918. Islamabad was chosen as the site of the consumer survey as it is an urban setting with significantly higher education and income, and consumers were expected to be relatively more aware of the agricultural pollution and its impacts for human health and the natural environment. Furthermore, since the present research proposes the changes in existing agricultural practices used in tomato crop, it was hoped that the citizens in Islamabad might have a better understanding of the importance of cleaner food.

2.3.2 Tomato crop

Tomato is an important vegetable which is used on a daily basis in Pakistani households. It is produced twice in a year and the cultivation is done in both spring and autumn. It is mostly consumed as salad and co-cooked with almost all Pakistani dishes. The products of tomato, for example, paste, dip, juice, ketchup, etc. are widely used in kitchens everywhere. Furthermore, tomato, onion, and chilies are also common vegetables in South Asian countries as they are co-cooked with other vegetables, pulses, and meat. Hence, the demand for tomatoes is relatively inelastic in Pakistan. Tomatoes are grown in all four provinces of Pakistan. According to Agriculture Statistics of Pakistan 2010-11, the vegetable has various varieties that are grown over an area of about 52,300 hectares. The annual production of tomatoes in Pakistan is estimated at around 530,000 tonnes.

Table 2.4: Tomato crop area and production

Description	Pakistan	Punjab
Area ('000'hectares)	52.3	6.7
Production ('000' tonnes)	529.6	87.8
Yield in tonnes per hectare	10.1	13.1

Source: Agriculture Statistics of Pakistan 2010-11

From producers’ point of view, tomato is an important vegetable crop as it yields significant net revenues in addition to employment opportunities in rural areas as it involves more labor inputs as compared to the other crops. Tomato is produced in various districts of Punjab, but Rahim Yar Khan, Muzaffargarh, Sheikhupura, Khanewal, Khushab and Gujranwala generate the highest per hectare returns on tomato crop. The suitable soil for tomato cultivation in Pakistan is clay loam, sandy loam, sandy clay loam, loam, silt loam. Tomato cultivation in Pakistan requires a warm climate, hence the suitable tomato cultivation temperature is between 12 °C and 29 °C.

The survey of this research is administered with tomato farmers in Khushab. Tomato farmers in Khushab however face several problems with regards to tomato cultivation which they have highlighted during the surveys. For example, tomato seed which is imported from various countries is very expensive, contributing to higher production cost of tomatoes. Farmers also face the problem of low farm gate price, and they have shown their frustration for not having any support from the government. Low farm gate price and a lack of support from the government negatively affects their motivation to grow tomatoes.

2.3.3 Supply chain

The production of tomato crop in Khushab is designed for widespread distribution and sale in larger markets. This, for example, is supplied to wholesalers in different vegetable markets including Islamabad, the consumer survey site. Since tomato crop is one of the main sources of farm households' livelihood in the study area, its supply chain is relatively better in terms of procurement, packing and transportation. The supply of tomatoes from Khushab to Islamabad is moderated through procurement agents who procure the produce from tomato farmers. Sometimes, these agents are facilitated by village dealers, who purchase small quantities of produce for them from the farm gate.

The agents supply the tomatoes to different markets where they have contacts with wholesalers. Wholesalers, for example, in Islamabad get the supply of tomatoes from these agents and sell to the shopkeepers in different markets in Islamabad who pick the produce from wholesalers. One of the reasons that tomatoes cultivated in Khushab are supplied to Islamabad is that it is one of the nearest markets as shown in study areas map (Map 1). Nevertheless, the supply chain of tomato crop cultivated in Khushab has some problems as well. For example, producers' difficulty in adaptation to the changing conditions, long-term capital investment, quality assurance, favourable terms with agents, logistics of production locations, technology adoption, and product credence.

In Pakistan, agricultural marketing is predominantly a private sector activity. There are some established private sector businesses which collect, transport, store, and assemble rural produce and trade within as well as outside the country. Most of the operations of these companies and groups target the urban areas. Often the factor and product markets are linked at the retail/wholesale stage through the commission agents who play the role of input suppliers and produce procurers/purchasers and in some cases, agents also provide inputs on credit to farmers. While agents provide crucial services, they are mostly exploitative in nature. At least, this is their impression in most of the cases.

However, the supply and value chains in Pakistani agriculture are generally weak and inefficient. For example, the existing infrastructure such as rural roads, warehouses and storage facilities, energy supply, and agricultural markets are not good. Furthermore, there is lack of innovation, product diversification, enterprise, trading sophistication, value addition and use of technology. Introduction of new products, appropriate packing, and marketing are also not upto the mark. Rural farmers often suffer in terms of limited opportunities for acquiring finance to invest in improving their farming systems. The weaknesses in the rural infrastructure such as communication and transport, postharvest processing, bulk handling, or specialized product movement facilities are compounded by an uncertain business environment.

The improvement in supply and value chains requires the development of rural infrastructure, finance and credit, improved coordination and use of modern technology. Farm to market linkage is also weak in Pakistan, which impedes farmers' access to nearest markets, hence they rely on agents and middlemen. There is a need for reforms in specific commodities, which could enhance farm productivity and energize the rural commodity markets by improving the access to credit and business development services. This could be achieved through targeting the growth of small and medium-scale farming.

2.4 Farm households' assets, machinery, and labour

Farm household assets are important as they have an impact on production efficiency, farm household incomes, and rural poverty. The main assets that farm households own in Pakistan include land, livestock, poultry, and agroforestry. However, it is well documented that there is inequality in farm households' asset ownership in Pakistan. For example, the distribution of land ownership in Pakistan is unequal, even though it is a crucial asset in the rural economy. Land ownership however affects the farm households' socioeconomic status, including ownership of other assets. For example, livestock is largely dependent on land as it provides fodder in addition to grazing service. Similarly, land ownership also affects farmers' access to credit as it could easily be used as a collateral.

Farm machinery however has less variations in Pakistan as farming in Pakistan is not fully mechanised (Akram et al. 2020). Furthermore, farm machinery is often procured by small and medium farmers on a temporary basis as ploughing and thrashing service providers are available in farming areas. According to the Pakistan Agricultural Machinery Census 2004, Pakistan had around 400,000 tractors and 171,000 units of tillage machines, cultivators, disk plows, trolleys, and tube wells etc (GoP, 2004). While updated data on different types of agricultural machinery is limited, the Pakistan Economic Survey 2020-21 claims that the operational tractors in Pakistan are around 612,000 (GoP, 2022).

Furthermore, the survey reveals that the domestic tractor industry has played a significant role in fulfilling the requirements of tractors in Pakistan by increasing production and sales of tractors.

Agriculture sector in Pakistan employs roughly 38% of the labour force as more than 65-70 percent of the rural population depends on agriculture for its livelihood (GoP, 2022). Pakistani agriculture is labour intensive as it is less mechanised and various tasks are still performed manually. In addition, large household size in rural areas and availability of cheap labour are also the factors that contribute to the intensive use of labour in the Pakistani agriculture system.

The next section discusses the process of background information collection to design the present research.

2.5 Background information collection for survey design

2.5.1 Sources of information

It is crucial to gather relevant background information about the research problem and study area to design a primary survey. However, DCE survey design requires the collection of far more information which includes in-depth investigation about the potential attributes of the product or service that is being studied, study area, population and the overall research topic. This section documents the comprehensive and systematic process that was carried out to gather the information from primary as well as secondary sources to design the surveys of present research. In what follows is a discussion on the secondary information collection process.

a. Secondary sources of information

The first step to collect the background information was to use all available secondary sources such as the review of the relevant material. This includes review of the relevant literature, published reports such as Pakistan Economic Survey, grey literature about agricultural practices in Pakistan and other relevant documents and websites. The material was very helpful to extract the required information about the existing agricultural practices, intensive farming, and agriculture sector compliance to health and safety standards in Pakistan. This secondary information gave an overview of Pakistani agriculture and helped in crafting some specific questions to investigate from primary sources. Below is a brief description of the primary information collection process.

b. Primary sources of information

Primary information was collected by means of meetings with relevant organizations and experts and focused group discussions. Various organizations and individuals working in the food and agricultural sector in Pakistan were requested to provide the required information. In this regard, National Agricultural Research Centre in Islamabad, and Ayub Agriculture Research Institute in Faisalabad have provided useful information. The information collected from these two organizations was about overall vegetable cultivation, tomato crop practices, tomato cultivation areas, use of agrochemicals and irrigation methods for different crops including tomatoes. Vegetable experts from these two organizations were interviewed to investigate the extent of concentrated use of agricultural inputs in tomato crop, especially in district Khushab.

Vegetable experts had stressed on the need for modifications in existing farming practices to make the farming more sustainable. This information was very useful in the development of research questions and survey instruments. Several key informants from study areas were interviewed about the existing agricultural practices used in tomato cultivation. Their interviews and information helped in defining the level of proposed changes, i.e. reductions in the use of agricultural inputs, and adoption of efficient irrigation methods which are required to implement sustainable agricultural practices in tomato crop to produce cleaner tomatoes.

A few focused group discussions (FGDs) with tomato farmers in study areas were also arranged which further helped in determining the level of proposed changes in existing agricultural practices. The following list of topics was discussed during FGDs with farmers in study areas.

1. Farm size and large and small farmers
2. Per season average net income (PKRs) of small farmers and large farmers
3. Education of farm decision maker (years of schooling)
4. Household members working off-farm
5. Types of grain crops and vegetables being grown in study areas
6. Crop irrigation methods used in different crops and irrigation water sources
7. Farmers perceptions of reduction in the use of agrochemicals
8. Agrochemical use and information
9. Overall pest/insect incidence in a crop season
10. Agrochemical use frequency

However, the data and information about the current use of agricultural inputs in tomato crop was inconsistent from different sources of information. This issue was resolved by collecting the information from primary sources and comparing it with the secondary data published in relevant research articles, reports, and books. The background information gathered from secondary as well as primary sources helped considerably in the design of the two DCEs conducted in this research. However, a lack of DCE research in the food and agriculture sector in Pakistan was a limitation in survey design in many ways. For example, it was not sure if the farmers would be able to comprehend the choice scenarios supposed to be presented to them. Nevertheless, this challenge was resolved by conducting two pilots with actual survey respondents using appropriate visual aid in choice sets. Due to inadequate and inconsistent information, multiple sources of information including key informants were used to triangulate the facts to reduce the margin of error. Below is the detail of the information gathered from various sources and used in the design of this research.

2.5.2 Collected background information

This section presents the information which was gathered from several primary as well as secondary sources outlined above. Mainly, this includes information regarding tomato crop, agronomic practices, and farming details.

a. Tomato farming in Khushab

The collected information revealed that the average farm size in Khushab is two acres which means that generally farm size in study areas is small. Farming in Khushab comprises of both cereal and vegetable crops. The share of cereals is 35% whereas vegetables cultivation is 65%. Cereals include wheat and maize and vegetable crops are tomato, potato, cucumber, chillies, cauliflower, and turnip. Grapes, oranges, and peaches are the main fruits of the district. FGDs with farmers revealed that roughly there are 300 to 500 vegetable farms in the study areas which grow various vegetable crops, however, tomato is a main cash crop in the area as it is relatively more profitable. Consultation with wholesale dealers of tomatoes in Islamabad revealed that the approximate share of tomatoes which is supplied from Khushab (farmer survey site) to Islamabad (consumer survey site) is 10% of the total supply of tomatoes in Islamabad.

b. Agrochemical use in tomato crops

As mentioned above, tomatoes in Khushab are grown using crop intensification methods. Yet, interestingly, farmers reported during FGDs that there will be no significant loss of tomato crop with one third reduction in the use of pesticides if there are no serious disease outbreaks. They also think that, in case of a disease outbreak, crop yield may reduce by 15 to 20%. On the other hand, farmers think that approximately 30% tomato crop yield may reduce with one-third reduction in the use of fertilisers. Farmers believed that without agrochemical use, farming is not possible as land requires the minerals. They reported that the average use of pesticides is 1 litre per 2.5 acres if it is of good quality. Similarly, the current use of fertilisers is 50 kg per 0.5 acre while the recommended fertilisers use is 50 kg per acre. The reason for applying fertilisers double than the recommended amount is that it improves vegetable weight. Farmers reported that the common fertilisers types that are being used are diammonium phosphate (DAP), nitrophosphate, and urea (nitrogen, phosphorus, and potassium. Table 2.5 presents the reported use of fertilisers and pesticides in tomato crop in study areas.

The information presented in Table 2.5 was gathered from experts and tomato farmers. Experts were consulted for the recommended use of fertilisers and pesticides for tomato crop, whereas farmers revealed the actual amounts which they apply. It was observed during FGDs with farmers that they do not know which pesticide is used for a specific crop or specific disease. Furthermore, in some cases, farmers applied pesticides that were not even relevant. Similarly, some of them were not aware of the appropriate time and stage at which to apply the pesticides to their tomato crop, which leads to overuse of pesticides.

Table 2.5: Current fertilisers and pesticides use in tomato crop

Fertilisers	**Current use**	**Recommended use**
Diammonium phosphate (DAP)	100 kg/acre	50 kg/acre
Nitrophosphate	150 kg/acre	150 kg/acre
Urea	100 kg/acre	50 kg/acre
Pesticides		
Chloropyriphast	350 ml/acre	500 ml/acre
Amamycin	120 ml/acre	200 ml/acre
Polytrincey	250 ml/acre	120 ml/acre

For example, when the tomato crop is ready to be harvested, the stakes are high as even a mild attack can result in significant damage. Hence, farmers often apply pesticides just before harvesting which is preventive use of the pesticides and not curative use. It was also noticed that agricultural extension is not very effective as majority farmers use shopkeeper/producer advice to apply the pesticides. Some guidelines during the applications of pesticides to their crops can help in reducing the use of pesticides, but farmers were either not informed or not keen about this.

c. Irrigation methods

FGDs conducted with farmers revealed that the main source of irrigation water in Khushab is tube-well, which is roughly 60 to 70 percent of the total irrigation. The rest of the irrigation is done using canal irrigation water which comes from the river. Irrigation department regulates the irrigation water and charges farmers to provide the water although the charges are very nominal and flat. For example, a farm household pays on average 320 to 640 Pakistani rupees per acre for one crop season. The irrigation department opens the supply upon request of farmers. As is the practice in few other arid and semi-arid areas in Pakistan, cereal crops are grown with rainwater. There are two main irrigation methods, flood irrigation and furrow irrigation, which are used in Khushab district. However, most of the vegetables including tomato crop are irrigated using the furrow irrigation method. Furrow irrigation is better than flood irrigation, but it is still very old and inefficient compared to sprinkle and drip irrigation.

d. Proposed changes in tomato cultivation and DCE survey attributes

The collected background information was used to design the attribute tables used in primary surveys of the present research. This information helped in shortlisting the relevant attributes that could be used to create the experimental design and the choice situations for both farmer and consumer surveys. Table 2.6 presents an exhaustive list of attributes along with their description and the sources from where these attributes were taken. This attribute list was made from the collected secondary information; however, it was narrowed down by means of primary information. The design of the attribute tables used in actual surveys was informed by this list of attributes.

Table 2.6: Attribute selection

Attribute	Description	Source
Fertiliser band placement drill	A fertiliser band placement drill designed to enhance fertiliser efficiency i.e. save 50% phosphate fertiliser application and increase wheat yield by 10% and comparative save Rs. 4300 per acre.	Pakistan Agriculture Research Centre Islamabad Pakistan
Quality fodder production	There is shortage of Total Digestible Nutrients by 27.29 million tonnes and Digestible Protein by 1.68 million tonnes. Low quality fodder due to non-availability of high-quality certified seed. Annual import cost of fodder seed is Rs. 779 million. Lack of technical support, quality seed, fodder grower, and seed enterprises. Potential for business in certified seed and fodder. Fodder production requires low inputs comparing main crops.	
Bio-fertilisers for increasing crops yield	Environment friendly and helps in saving fertilisers and increases crop yields significantly. Integral part of sustainable agricultural practices and organic farming	
Short rotation crops	Develop and introduce short rotation crops and hybrid maize.	Framework for Implementation of National Climate Change Policy 2014 – 2030 (a follow-up of the National Climate Change Policy)
Integrated cropping	Adopt integrated cropping method to avoid monoculture and to have varieties of crops particularly in Balochistan.	
Low delta crops	Introduce low delta crops, at large scale, in Balochistan.	
Water storage and rainwater harvesting	Develop localized plans for water storage and rainwater harvesting for drought management. Train local communities to harvest rainwater in small ponds and dams.	
Contour farming	Promote contour farming in mountain areas.	
Improved irrigation	Make innovative technologies in agricultural irrigation such as and laser land levelling for reduced irrigation water consumption and discourage traditional flood irrigation practices.	
Canal lining	Ongoing canal lining be completed on priority to reduce irrigation losses.	
Cropping patterns & diversification	Ensure improvement in cropping patterns and crop diversification with optimized planting dates.	
Intercropping system & soil conservation	Introduce intercropping system such as legume rotation and soil conservation techniques.	

Improve livestock feed quality	At the farm level improve livestock feed quality by preparing supplements of Multi-Nutrient Blocks (MNB) prepared from urea, molasses, vitamins and minerals.	
Fodder production fodder crops	Provincial agriculture research organization and universities to supervise livestock feed and fodder production enhancement activities.	
Laser land levelling	Promote laser land levelling of agriculture fields to reduce water losses.	
Livestock feed	Encourage and assist farmers to develop cost-effective livestock feed through “Silage Making” techniques and by using “Urea Treatment” from maize, rice and wheat low quality roughages.	
Incentives for watershed management	Provide incentives to local population living in watershed areas to ensure plantation and sustainability through their concrete participation.	
Plant shrubs and trees	Afforestation and shrubs growth to reduce soil erosion and avoid silting of dams.	
Green manure use	Promote use of green manure in agriculture.	
Farm forestry and agro-forestry	Intensively encourage farm forestry and agro-forestry practices through plantation of multipurpose and fast-growing tree species to meet the demands of local population for fuel, timer and fodder for cattle.	
Crops insurance	Involve corporate sector, comprising of public and private insurance firms to build an agricultural production insurance system for agriculture sector of Pakistan, particularly focused on climate change related crop failures.	
Ground water recharge	For artificial ground water recharge, involve institutes that apply engineering innovations to irrigation techniques, particularly, suited for arid and hyper arid agriculture;	
Drought resistance crop varieties	Develop and introduce research-based drought resistance crop varieties.	
Laser land levelling Bed and furrow plantation Zero tillage	Laser land levelling, bed and furrow plantation, zero tillage have low land preparation and sowing cost, high average fertiliser use efficiency, high crop yield, and less labour cost comparing the conventional ploughing methods.	Evaluation of Resource Conservation Technologies in Rice Wheat System of Pakistan, PCRWR 2002.
Grass strips	Grass strips	Agricultural sustainability and technology adoption: issues and policies for developing countries David R. Lee
Crop rotations	Crop rotations, including grain	
Agroforestry	Agroforestry systems	
Intercropping	Intercropping and polycultures – legume intercropping	
Irrigation	Drip irrigation – micro irrigation-gated pipes, furrow irrigation by creating trenches or furrow	
Fallow management	Improved fallow management	
Rainfall harvesting	Rainfall harvesting and storage, micro- and macro-catchments	
Mulching	Mulching	

Integrated pest management	Integrated pest management, Contour farming & alley farming Soil aeration, Hedgerows and live barriers, raised beds, Improved use and efficiency of animal manures	Amer. J. Agr. Econ. 87 (Number 5, 2005): 1325–1334.

2.5.3 Pilots surveys

Before implementing the final surveys, two pilot surveys were conducted with tomato farmers and consumers. This is a standard practice as DCE design is created using priors which are collected from pilot surveys. Furthermore, pilots help in improving the survey instrument and experimental design. Pilot surveys' administration in rural tribal areas of Khushab was especially challenging due to farmer illiteracy, their reluctance to engage with outsiders, language and cultural barriers, and need for logistical support including off-the-road transport. To effectively engage with the farming community, local facilitators who were known in the farming community were used. Local facilitators introduced survey team in study areas in addition to providing useful information to carry out the field work smoothly. Field staff belonged to the same area, hence they were familiar with the language and cultural norms, which helped in communicating the research and explaining the survey instrument more appropriately.

Enumerators used to administer the surveys were undergraduate students which were recruited from a local university. Adequate training was imparted to the enumerators which included formal exercise of survey description and key questions and mock interviews with friends under supervision. However, each enumerator had a different style and language which he/she was going to use in conducting the interviews which was a challenge as different respondents might perceive the survey questions differently. To fix this problem, the survey tool was read to each enumerator several times and they were asked to interview me afterwards. Moreover, a uniform research introduction and survey pitch was prepared to assist the enumerators in explaining the research introduction, experimental design, and the survey questions.

A unique aspect of the DCE implementation in the present research is communal choices or joint decision making which was more noticeable in the farmer surveys. For example, respondents would consult their friends before making choices, which was something unexpected. Since the present research was designed for individuals and choices did not involve communal decision making, this was a challenge which was overcome by prompting the respondents to make choices by themselves. Pilot surveys furnished the priors which informed the experimental designs used in final surveys. Furthermore, pilots had considerably helped in refining the survey instrument e.g. modification of the survey questions.

The next chapter is Chapter 3, which presents a detailed discussion on the DCE methodology.

Chapter 3 Research methodology

3.1 Background

Over time, economic analysis has started investigating the themes that are less market oriented (Haab and McConnell, 2005), a trend which emerged as a result of the need for studying seemingly intangible and non-material aspects of economic welfare. This has necessitated the development and use of a range of non-market valuation methods to measure the extent to which resources are allocated efficiently, from the point of view of economic theory. The role of non-market valuation is more crucial for resource allocation decisions for public goods such as the environment due to externalities, poor property rights and resultant market failures (Haab and McConnell, 2005).

Environmental valuation measures the non-market benefits and costs, both of which have an important role in public-sector decision-making processes. It guides policy makers about the possible costs of different policies to protect the environment, and the expected benefits in terms of improved citizens' welfare. Hence, non-market valuation compares the returns on investment on environmental protection, and the possible costs of lack of action. This includes the estimation of compensation to the public when private action harms the public good. Non-market valuation also attempts to observe individual behaviours in response to a change in public goods and infer individual preferences as well as the value of this change (Haab and McConnell, 2005).

In order to reveal individual preferences as well as the value that individuals place on changes in a public good, researchers need some empirical evidence. This empirical evidence can be established by analysing individual preferences using suitable non-market valuation techniques. The common non-market valuation techniques include the contingent valuation method (CVM), hedonic price method (HPM), travel cost method (TCM) and discrete choice experiment (DCE) modelling. These valuation techniques are frequently used in health, transport, marketing, agriculture and environmental research.

The present research models farmer and consumer preferences for sustainable agricultural practices in the Pakistani context using a DCE approach. DCE is a survey-based quantitative non-market valuation technique, pioneered by Louviere and Woodworth (1983) and developed by Hensher et al., (2005) and others. DCE has its theoretical foundation in random utility theory and assumes economic rationality and utility maximization (Hall et al., 2004). This technique is used for eliciting individual preferences for goods and services where it is not possible to use the revealed preference data of actual choices made by individuals (Mangham et al., 2009). It helps in identifying the underlying influences on individuals' choice behaviour and how these form their preferences (Hensher et al., 2005).

Identifying the influences that affect individual preferences is central to choice analysis (Hensher et al., 2005). Thus, it is a challenge for researchers to detect and assess the information that individuals use when they make choices. The real task in choice analysis is to explain the choices of the target population, as preferences often vary across individuals and may exhibit a large amount of variation. DCE considers individuals as decision makers and explains their choices using experimentally designed hypothetical alternatives. Each alternative is described by several characteristics, known as attributes. Using one of the attributes as a monetary payment allows researchers to uncover the value that individuals place on selected attributes (Mangham et al., 2009).

These alternatives should be mutually exclusive from the respondents' perspective (i.e. the choice of one alternative implies not being able to choose the other), all possible alternatives should be included and there must be a finite number of alternatives (Train, 2003). An individual is assumed to choose the alternative that yields maximum utility, which depends on the utilities associated with attributes and attribute levels in an alternative (Lancaster, 1966). In DCE, a set of alternatives is called a choice set or a choice situation, which usually has two or more alternatives. A respondent faces multiple choice sets in a DCE experiment. DCE helps in explaining heterogeneity in preferences across a sample of individuals (Hensher et al., 2005), who are asked to value different alternatives in a choice set.

DCE is considered powerful compared to other valuation techniques because it determines the significance of attributes that describe a good, service or policy scenario (Mangham et al., 2009). In addition, it unveils the relative importance of attributes by investigating the extent to which individuals are willing to trade-off one attribute for another (Drummond et al., 2005). Information on the relative importance of certain attributes of a good, service or policy can be very useful for those involved in policy making and resource allocation decisions (Baltussen and Niessen, 2006).

DCE uncovers the marginal utility, in terms of willingness to pay (WTP) or willingness to accept (WTA), for a unit change in attributes as well as attribute levels. This is also considered a strength of this methodology, in comparison with other techniques, as DCE offers more detailed information on welfare estimates, i.e. WTP or WTA. Furthermore, DCE results can be analysed for sub-groups of the collected sample and it is possible to consider the impact of socioeconomic characteristics on the valuation of different scenarios (Mangham et al., 2009).

DCEs have been applied in a range of fields including, but not limited to: marketing, health, transport and environment in higher income settings (Mangham et al., 2009). However, there are relatively fewer studies from lower income and under-developed contexts. This study implements DCE in the context of a developing country, i.e. Pakistan, to investigate farmer and consumer preferences for sustainable agricultural production by proposing changes in current agricultural practices.

3.2 DCE choice analysis

To investigate citizens' choices using the DCE approach, data are gathered and analysed on individual preferences. Researchers use two approaches to gather the data on individual preferences to estimate the models. The first approach is the indirect approach, which entails the collection of revealed preferences data. However, the second approach involves the direct investigation of stated preferences data. Below is the `description of both approaches:

3.2.1 Revealed preferences

Revealed preferences (RP) represent the actual choices made by individuals in a market setting, and data on RP are collected from events that have already occurred (Hensher et al., 2005). The data are called 'revealed preferences' because people reveal their tastes and preferences by making real choices (Train, 2003). There are several ways an analyst may collect the data on revealed preferences. The common approach to collect the data on revealed preferences is to observe a market and record individuals' choices in choosing or not choosing an alternative. This data can be collected either from a secondary source, e.g. record of shopping, or by asking individuals to observe the choice within a market.

The key concern in RP data collection for an analyst is to be able to collect data on attributes as well as socioeconomic characteristics of the respective individuals. The use of RP data has its own advantages and disadvantages for non-market valuation. For example, the collection of RP data denotes individuals' real-life choices that can reveal information about the demand for a certain good or service in a market (Train, 2003). This implies that if RP data are collected on a representative sample of the population, the actual market share of a good or service could be found. Furthermore, the choices are made in the presence of real constraints faced by individuals, which limit these choices. Thus, RP data has the properties of reliability and validity as it represents the real choices made in an actual market.

However, there are some limitations to collecting the RP data, as, for example, it is only available on existing alternatives (Train, 2003). Hence, new attributes and attribute levels are missed, which affect individual choice behaviour. Lack of data on new alternatives restricts researchers from studying market changes and innovation (Hensher et al., 2005), in addition to limiting *ex-ante* analysis required for market research. Furthermore, in some cases, there is no or very limited variation in price, which impedes the analysis (Train, 2003), while it is also impossible for researchers to collect the data on alternatives which were not chosen. The present study is conducted in the context of a developing country, i.e. Pakistan, where RP data are even more difficult to collect due to informal businesses, poor record keeping or lack of records for individual choices of products and services.

3.2.2 Stated preferences

Stated preferences (SP) represent the choices made by individuals in hypothetical situations rather than in real market settings (Hensher et al., 2005), and data on SP are collected from events that have not yet occurred, and may never occur. SP data are collected through surveys where individuals face hypothetical choice situations (Train, 2003). The term 'stated preferences' means that people state their choices in hypothetical situations and this type of data is also known as stated choice data. In SP, experiments could be designed with as much variation in each attribute as is necessary (Train, 2003) and are not constrained by real world limitations. Unlike RP data, price may be varied by analysts, so they can assign a sufficient range of prices to alternatives, which in reality may not occur. In SP data, respondents' personal constraints, e.g. income, are not considered as constraints while making choices due to hypothetical choice settings.

In SP surveys, the hypothetical scenarios or choices have to be framed in such a way that they look as real as possible so that respondents take the tasks seriously. SP relaxes the main limitation of RP in which data is only available on existing alternatives as attributes and attribute levels are fixed. The SP approach, however, allows the collection of data outside the range of existing alternatives. The collected data is used in modelling individual preferences for attributes and the attribute levels of hypothetical goods and services, which enables the investigation of demand for new products and their attributes (Louviere et al., 2000).

Many goods are not traded in real markets, hence, SP data help in exploring their scope (Train, 2003; Louviere et al., 2000). In SP experiments, the attributes and attribute levels are identified and their hypothetical relationships are specified in advance. In addition, SP data permits us to collect multiple observations over the number of choice sets completed, which is its strength, unlike RP data that provides only as many observations per individual as the market allows for.

The main, and perhaps the biggest, shortcoming of the SP data is its hypothetical nature that leads to hypothetical bias. Respondents might not be completely aware or certain of what they will do if a hypothetical situation becomes real (Train, 2003). There is also a question of whether the models estimated from SP data offer equally reliable estimates and can predict real market behaviour

(Louviere et al., 2000). Moreover, there are a number of other factors, e.g. the underlying reasons of respondents' choices, their perception of the interviewer etc., that affect hypothetical choices, which might not arise in the real choices. In general, however, the estimates are reliable when respondents understand and can respond to choice tasks (Louviere et al., 2000).

However, it would be more useful to combine SP and RP data as this can yield more robust results, (Louviere et al., 2000). In doing this, the benefits of both approaches could be reaped while mitigating their limitations. The SP data can provide the variation in attributes, whereas the RP data can provide a more realistic picture. However, this might not be possible in every situation, especially in developing countries.

3.3 DCE theory

Individuals make decisions all the time by comparing different alternatives in a choice situation. The challenge is to find a way to identify and capture the information that the individuals use while making choices. A conceptual framework is needed to identify the underlying influences on individuals' choice behaviour (Hensher et al., 2005) to study their heterogeneous preferences. Studying preference heterogeneity has become an important part of choice analysis to explain variability in the behavioural responses of agents in different choice situations (Hensher et al., 2005).

DCE is a useful tool to investigate citizens' preferences by analysing the heterogeneity in their choices. Here, a framework needs to be set out within which one can capture the sources of behavioural variability in individual decision-making using a DCE approach. DCE has a solid theoretical foundation that is grounded in Lancaster's theory and random utility theory. These theories underpin DCE implementation as a research methodology and inform results interpretation. The description of both theoretical frameworks is presented below.

3.3.1 Lancaster's theory

In the 1960s, the traditional economic theory of consumer behaviour was challenged by Lancaster, who had developed a new approach to explain choice behaviour. Lancaster presented this in 1966 and referred to it as 'A New Approach to Consumer Theory'. According to this approach, goods are not the objects of utility, which was believed prior to the 1960s; instead consumer utility is derived from their characteristics or attributes (Lancaster, 1966; Alcaly and Klevorick, 1970). A good will possess more than one characteristic and goods share their characteristics. Utility or preference orderings, according to this theory, are exercised on the basis of the characteristics of the goods they possess.

Furthermore, consumption of a single good that yields utility in terms of multiple properties of good is characterized by joint outputs. Different goods possess different characteristics in different magnitudes, as per Lancaster's thesis. A key inference of this is that goods hold innate differences and they can be distinguished based on their attributes. This also implies that the value placed on each characteristic of a good can be estimated to reveal the value of a good or service as a whole (Ryan, 2004).

This is the theoretical basis of the DCE approach, where consumers value the particular features or attributes of the goods as opposed to the goods as a whole. The DCE approach uses this theory in the development of choice sets which have alternatives comprising different attributes and attribute levels. In the DCE context, when a good or service is valued, there are different attributes with different levels that denote the variation in characteristics of the goods.

3.3.2 Random utility theory

Following Hensher et al., (2005), overall utility of an alternative in a choice situation is represented as 'U_i', where 'i' refers to a specific alternative, e.g. bus or train. Utility is a relative measure and the question is the level of utility that is associated with one alternative relative to the other alternative in a choice situation. It is important to mention here that the sources of utility in an alternative are attributes or characteristics of an alternative, which establish the level of utility associated with an alternative in a choice situation. This also implies that the utility of each alternative could be compared. Since there are aspects of the individual decision maker's utility that cannot be observed, the overall utility 'U_i' associated with the ith alternative can be decomposed into an observable 'V_i' and an unobservable component 'ε_i'. Here, 'ε_i' refers to the unobserved influences as error.

In choice analysis, both 'V_i' and 'ε_i' are of great importance as these help in uncovering the sources of variability in behavioral response in both parts of the utility expression. Assuming a relationship between these two components which are additive, we can write this expression:

$$U_i = V_i + \varepsilon_i \tag{3.1}$$

$'V_i'$ is the 'representative component of utility' as it represents the set of attributes that are observed and measured for a representative individual 'q'. This contains a set of weights that establish the relative contribution of each attribute to the observed sources of relative utility. This representative utility component is a linear expression where each attribute has a unique weight known as a parameter or coefficient that accounts for the attribute's marginal utility. Since the functional form can be different for each attribute, the generalized notation for functional form is as follows:

$$V_i = \beta_{0i} + \beta_{1i} f\,(X1i\,) + \beta_{2i} f\,(X2i\,) + \beta_{3i} f\,(X3i\,) + \cdots + \beta_{Ki} f\,(XKi\,) \tag{3.2}$$

$'\beta_{0i}'$ alternative-specific constant, which represents on average the role of all the unobserved sources of utility, hence this parameter is not associated with any of the attributes.

$'\beta_{1i}'$ is the weight or parameter of attribute $'X1'$ and alternative $'i'$. Here, $k = 1, \ldots, K$ attributes. The subscript on every element denotes that the weights, the attribute levels, and the constant are specific to the $'i$th' alternative. And $f(\ldots)$ shows that there can be different ways that the attributes enter the utility expression, for example, they can be treated as linear and could also be specified in a non-linear form. The assumption is that the $'V_i'$ component is linear additive in the attributes and the parameters that each parameter is a single fixed estimate and not a random parameter with a mean and a standard deviation.

On the other hand, $'\varepsilon_i'$ is an index of unobserved influences which is behaviorally unknown. Hence, it is right to assume that across the sample of individuals, everyone will have some utility associated with an alternative that is captured by the unobserved component $'\varepsilon_i'$. This means that there will be a distribution of such unobserved sources of utility across the sampled population which is unknown.

There are two assumptions that are taken for this:

1) The unobserved utility associated with each individual is located on some (unknown) distribution and randomly allocated to each sampled individual.
2) Each alternative has its own unobserved component represented by some unknown distribution with individuals assigned locations randomly within the distribution that defines the range of utility values. While $'\varepsilon_i'$ is different across alternatives, it can have correlation across alternatives. However, it is assumed for simplicity that each unobserved component is independent with the exact same distributions (i.e. identically distributed) and has its own unique mean value. These assumptions are referred to as the IID (independently and identically distributed) condition. Under IID, each unobserved component is identically distributed, and all covariances are set to zero since the alternatives are independent. While IID assumption is an appropriate starting position for choice analysis due to its simplicity, it is behaviourally restrictive. Nonetheless, IID assumption is used to conveniently estimate and interpret the output of a basic choice model. The 'βs' are assumed to be random parameters, except the conditional logit model which is a basic choice model with fixed coefficients, following a specific distribution (such as normal, log normal, uniform or triangular) to capture unobserved heterogeneity across individuals.

The above assumptions yield three useful insights, first, the attributes that are not included in the observed part of the utility expression are represented by the unobserved component and of identical impact for each alternative. Thus, if one attribute is missing in all alternatives, it is expected to have the exact same influence of this on the choice of each alternative, second, an attribute that is common to two or more alternatives suggests the presence of correlation across alternatives. If it is excluded from the observed part of the utility expression, then its inclusion in the unobserved component must introduce correlation between alternatives, third, there is a concern about possible violation of constant variance and/or correlated alternatives because of an inability to accommodate the sources of this in the observed part of the utility expression, one should consider a choice model that allows less restrictive assumptions.

Now we can translate the behavioral choice rule and associated assumptions into a model that can be used to estimate the parameters that represent the contribution of attributes and socio-demographic characteristics of alternatives to the overall choice outcome. The assumption is that an individual acts rationally while comparing the alternatives and chooses the alternative which gives the maximum level of utility. In other words, an individual acts as if they are maximizing utility. Due to the lack of information, the analyst can explain an individual's choice only up to a probability of an alternative being chosen.

Using the utility expression notation used in (3.1)

An individual will evaluate each alternative as represented by $'U_j;\ j\ =\ 1,\ldots,J'$ alternatives.

The individual decision maker's rule is that they will compare $'U_1, 'U_2, \ldots, 'U_j, \ldots, 'U_J$ and choose the one with maximum utility, $('U_j)$.

Here, an individual's behavioral choice rule is as follows. The probability of an individual choosing alternative 'i' is equal to the probability that the utility associated with alternative 'i' is greater than or equal to the utility obtained from alternative 'j'after evaluating each alternative in a choice set of $'j = 1, \ldots i, \ldots J'$ alternatives.

In probability notations,

$$Prob_i\ =\ Prob\ (U_i\ \geq\ Uj\ )\ \forall\ j\ \in\ j\ =\ 1,\ldots,J\ ;\ i\ \ \neq j\ ) \tag{3.3}$$

This is equivalent to:

$$Prob_i\ =\ Prob\ (V_i +\ \varepsilon_i) \geq (V_j +\ \varepsilon_j)\ \forall\ j\ \in\ j\ =\ 1,\ldots,J\ ;\ i\ \ \neq j\ ) \tag{3.4}$$

Equation (2.4) could be examined through a set of observable attributes and the information that is not observable, i.e. 'ε_{ij}'. This lack of full information suggests that the individual decision maker's utility maximization is based on random utility maximization rule.

By re-arranging equation (2.4):

$$Prob_i \;=\; Prob\;(\varepsilon_j - \varepsilon_i) \leq (V_i - V_j)\;\forall\, j\; \in\; j \;=\; 1,\ldots,J\;;\; i \;\neq j\;) \tag{3.5}$$

This implies that the probability of an individual choosing alternative $'i'$ is equal to the probability that the difference in the unobserved sources of utility of alternative $'j'$ compared to $'i'$ is less than (or equal to) the difference in the observed sources of utility associated with alternative $'i'$ compared to alternative $'j'$ after evaluating each and every alternative in the choice set of $'j\;=\;1,\ldots i,\ldots J'$ alternatives. Randomness in the utility maximization rule comes from unobserved elements of utility 'ε_j'associated with each alternative in an individual choice. This is a way to account for the unobserved elements of the utility expressions associated with each alternative.

In DCE, the marginal utility estimates are derived in terms of price premium (WTP) or compensations (WTA) for the attributes of a hypothetical good or service. In term of equivalent variation, price premium is the amount of compensation paid by consumers to the farmers that will leave the consumers in their subsequent welfare position in the absence of the price change if they are free to buy any quantity of the commodity at the old price. In terms of compensating variation, it is the amount of compensation that will be received by the farmers that will leave them in their initial welfare position following the proposed change in agricultural practices.

There are two methods to calculate the marginal utility estimates, preference-space and WTP or WTA-space. The difference is of the distributional assumptions that can be placed in two ways. A model in preference-space is specification of the coefficient distribution in the utility function and derivation of the distribution of willingness to pay (WTP). In this case, utility is represented by coefficients of the attributes. However, a model in WTP or WTA-space involves the specification of the WTP or WTA distribution and derivation of the distribution of coefficients. In this case, WTP or WTA is estimated directly, through a re-parameterization of the model.

In other words, utility estimation in preference-space involves estimating the model in the usual way and calculating marginal WTP as the ratio of parameters. This is the conventional method where the marginal utility estimates are converted into marginal WTP estimates for a change in the level of a specific attribute that contributes to the increase in utility.

Along an iso-utility curve one can substitute money $'x_\$'$ for an attribute $'x_1'$, keeping the utility level unchanged ($dU = 0$):

$$dU = 0 = d(\beta_1 x_1 + \beta_\$ x_\$) = dx_1 \frac{\partial U}{\partial x_1} + dx_\$ \frac{\partial U}{\partial x_\$} = 0 \rightarrow dx_1 \frac{\partial U}{\partial x_1} = -dx_\$ \frac{\partial U}{\partial x_\$} \rightarrow dx_1 \beta_1 = -dx_\$ \beta_\$ \rightarrow \frac{dx_\$}{dx_1} = -\frac{\beta_1}{\beta_\$}$$

In order to calculate the marginal prices (MP) for an attribute, negative ratio of the coefficients (β_s) of respective attribute (β_1) and the coefficient of the price attribute($\beta_\$$) are taken.

$$MP\ (WTP) = -\ \beta_1/\beta_\$ \tag{3.6}$$

or

$$MP\ (WTA) = \ -\beta_1/\beta_\$ \tag{3.7}$$

WTP or WTA-space is an alternative approach to compute the welfare estimates by reformulating the model so that marginal WTP or WTA is estimated directly. This approach is called utility estimation in WTP-space and this method produces estimates of WTP distributions that are less dispersed (see following section 2.5.3 for further detail).

WTP estimates in this study represent the economic value a consumer places on proposed changes in existing agricultural practices to improve human health and the natural environment, whereas the WTA indicates the compensation required to pay farmers to implement the desired changes. In addition to usual welfare estimates, i.e. WTP or WTA, for attributes, the impact of respondents' socio-demographic characteristics on welfare estimates is also investigated.

3.4 DCE design and implementation

This section explains the steps involved in designing the DCEs used in this research. It includes a discussion on attribute selection, experimental design, questionnaire development and their implementation.

3.4.1 Attributes selection

The first step to design a DCE after identifying the research problem and research questions is to identify the relevant attributes. The selection of attributes that matter to the study population in a given context is a crucial issue and must involve extensive enquiry to select the attributes that influence individual choices (Hensher et al., 2005). The DCE attributes used in the present research represent the proposed changes in current agricultural practices used in tomato cultivation in study areas. Sufficient background information was collected and used to design the attribute tables in order to minimize the unobserved sources of influence on respondents' choice behaviour. This includes a review of literature (relevant DCE studies on farming practices and food attributes) and information regarding crops, use of agrochemicals, and irrigation practices in the Pakistani context. The secondary information was supplemented with in-depth interviews with experts from the agriculture departments and farmers. The gathered information helped in identifying the most relevant attributes and attribute levels that represent more realistic changes.

The selected attributes were measurable and respondents could easily decipher their levels in terms of quantitative scales. Furthermore, the attributes identified for the farmer and consumer surveys have a clear role in determining respondents' utility. Table 3.1 presents the attributes used in both famer and consumer surveys. The attribute table used in the consumer survey includes five attributes such as irrigation method, fertiliser use, pesticide use, inspection and a cost attribute in terms of price premium. Each attribute except price premium has two levels: first level denotes the smaller changes (in current agricultural practices used in tomato cultivation) and the second level signifies greater changes. Below is the detailed description of these levels. Furrow and drip irrigation are the two levels of irrigation method attribute which indicate the changes proposed to improve the irrigation efficiency. Furrow irrigation saves roughly 50% water compared to flood irrigation (which is the current irrigation practice in Pakistani agriculture), and drip irrigation saves almost 70% water compared to flood irrigation. The two levels of fertiliser use attribute are one-third reduction in their current use and a half of their current use. Similarly, one-fourth and one-third reductions in current use of pesticides are the two levels of pesticide use attribute.

Table 3.1: Attributes description

Proposed changes attributes	**Attribute levels**
Irrigation method	Furrow irrigation, drip irrigation
Fertilisers use	33% lower use of fertilisers, 50% lower use of fertilisers
Pesticides use	25% lower use of pesticides, 33% lower use of pesticides
Inspection	Two times inspection per crop season, four times inspection per crop season
Price premium/kg (Rs.) for farmers	2, 4, 6, 8, 10 additional for each kilogram of tomatoes
Price premium/kg (Rs.) for consumers	10, 15, 20, 25, 30 additional for each kilogram of tomatoes

Inspection attribute signifies the farmer compliance to the proposed changes in farming practices. The two levels of the inspection attribute are two times inspection per crop season and four times inspection per crop season which are the proposed changes. The last attribute in the attribute table is the price premium which is the amount of money that consumers will pay and farmers will receive as an incentive to implement the proposed changes. In other words, the price premium on cleaner produce is a compensation paid to the farmers for adopting the proposed changes which entail some cost (Table 1). The premium in this context refers to the additional or extra price per kilogram of tomatoes that consumers must pay to get the cleaner produce (tomatoes). Since the premium will be charged on the tomato price, the payment vehicle in this case would be the price. Unlike other attributes, price premium has five levels to accommodate a sufficient variation in the price premium. Status-quo for the irrigation method is flood irrigation, unrestricted use for fertiliser and pesticide use attributes and no inspection for the inspection attribute.

The attribute table used in the farmer survey is slightly different as the inspection attribute was dropped to reduce the cognitive burden and make it convenient for farmers to understand the choice situations. Furthermore, the first level of the irrigation method attribute (furrow) was also removed after the first pilot, as it was already being used in tomato cultivation. Similarly, the price premium used in the farmer attribute table was lower as it was set considering the tomato farm gate price, whereas the price premium in the consumer attribute table was according to the market price of tomatoes which was greater than the farm gate price. This is why there are two price premium attributes in attribute table (Table 3.1), first represents the farmer survey price premium and the second is for the consumer survey.

The attribute levels used in the present research have significant policy relevance as the empirical evidence on these attributes could inform policy makers in designing several interventions outlined in the Agriculture and Food Security Policy, the National Water Policy, and the National Sustainable Development Strategy of Pakistan. For example, adoption of efficient irrigation, improvement in farm gate price and agricultural sustainability are some of the areas that these policies have highlighted, and the information on citizens' preferences of the listed attributes could be very useful in the design of projects for sustainable agriculture.

The choice situations created from the attribute tables included the visuals to help respondents clearly understand the stated changes. Visualization techniques are common in stated preference studies as they help respondents comprehend complex DCE choices, convey realistic change scenarios, and reduce reliance upon response heuristics[2] (Bateman et al., 2009). Furthermore, visuals help reduce the fatigue of respondents, prevent tiring effects (Dijkstra et al., 2003) and thus measure underlying preferences more effectively.

3.4.2 Experimental design

The DCE data-generation process relies on experimental design, hence it is considered as a foundation for a DCE study (Hensher et al., 2005). Experimental design is a combination of attributes and attribute levels and is used to construct the alternatives included in the choice sets presented to respondents (Hoyos, 2010). Creation of an experimental design involves a step-by-step process, which starts from defining the research problem, understanding it, and establishing the research questions and hypotheses. Once the research problem is defined and hypotheses are established; the attribute table (discussed above in attribute selection) is then used to produce the experimental design using a design software. The experimental designs for this research were created using Ngene software.

[2] Response heuristics are response biases that refer to simple, efficient rules people often use to form judgments and make decisions.

Experimental designs were generated by specifying the statistical properties of the design such as design type, design efficiency, and choice of labelled and unlabelled design. While creating the design, it is also fundamental to specify the number of alternatives and the number of attributes that will form each alternative (Hoyos, 2010). The design software gives output; as per specifications of attributes, attribute levels and alternatives; in the form of code which is used to generate the choice situations. For the present research, the design code from Ngene was copied in Microsoft Excel spreadsheet to create the choice situations using Microsoft Excel formulas. The choice situations were incorporated in the primary surveys along with the questionnaires in the form of choice cards. The choice cards presented hypothetical alternatives from which respondents then made the choices.

The DCE experimental design is created using priors which are tentative values for the parameters to be estimated through the experiment. However, since the values of these parameters are unknown before performing the experiment, pilot surveys are used to obtain the priors. Pilot surveys are administered with a small number of actual respondents. However, there is a need for priors even to implement the pilot survey. So, an orthogonal design was used for the first pilot which furnished the priors for the second pilot. An orthogonal experimental design is an experimental design that satisfies attribute level balance, and all parameters are independently estimable. Hence, the attribute levels for each attribute column in the design need to be uncorrelated in an orthogonal design (ChoiceMetrics, 2018). The orthogonal design attributes are statistically independent with a zero correlation, and since orthogonality is the main criterion, design efficiency is hardly considered.

However, it is desirable to use optimal or statistically efficient design. An efficient experimental design minimizes the correlation in the data for estimation purposes, imparts information about attribute parameters, and yields data to estimate the model parameters with low standard errors (Hensher et al., 2005; ChoiceMetrics, 2018). The optimal or efficient designs optimize the amount of information obtained from a design under specific assumptions. While optimal designs may be statistically efficient, unlike orthogonal designs, they are likely to have correlations. There are some assumptions commonly imposed on efficient designs. For example, the assumption of attribute level balance that all attribute levels appear equally in the data set, which intuitively provides a good basis for estimation. Similarly, the outcomes of all choice situations from the same respondent are assumed to be independent, and that all respondents face the same choice situations.

Efficiency of a design is a measure of the level of precision in which effects are estimated (Hoyos, 2010). There are various efficiency measures, for example, D-efficient designs minimise the determinant of the variance–covariance matrix of the model to be estimated (Hensher et al., 2005). A-efficiency is achieved when the trace (i.e. the sum of the diagonal) of the variance-covariance matrix is minimised. However, D-efficiency is preferred over A-efficiency because it takes into account the whole variance-covariance matrix, not only the standard errors of the estimated parameters. From the statistical point of view, optimal designs are preferred, however, there is a need to take into account some other issues from an empirical perspective, for example, task complexity, heuristics and the inclusion of a status quo option (Lancsar and Louviere, 2008).

Finding D-efficient designs is a time-consuming effort. Given a model specification with a set of priors, this is assumed to be the true model. For such a model, there are many possible experimental designs, i.e. possible combinations of attribute levels for each alternative. Then, as both the model parameters (priors) and design matrix are known, it is possible to calculate the variance-covariance matrix of the model. This is done analytically for the case of the multinomial logit model, or through simulation for the case of mixed logit model. After testing many different possible designs, the one with the smallest determinant of the variance-covariance matrix (D-efficient) is selected as the optimal design (Choice Metrics, 2018).

In what follows is a brief description of the designs used in this research.

a. Orthogonal design

To collect the priors for efficient design, the first pilot was conducted using an orthogonal experimental design with randomized attribute levels to create the choice situations. In the orthogonal designs category, it was optimal orthogonal in the differences (OOD) design that was used in this research. It is a special type of a sequential orthogonal design. While maintaining orthogonality, experiments are constructed in such a way that attributes common across alternatives never take the same level over the experiment (Choice Metrics, 2018). Hence, OOD design attempts to maximize attribute level differences. Furthermore, respondents must trade on all attributes in the experiment and orthogonality of the design ensures the determination of independent influence of each attribute on choice. However, this type of designs has two limitations: a) this is only constructed for unlabelled experiments, b) these designs may promote certain types of behavioural response, such as lexicographic choice behaviour.

The OOD design used in this study was an unlabelled design, which means that the headings of each alternative were generic and did not guide the respondents. Instead, respondents chose alternatives using the information of attributes and attribute levels. This design was created using Ngene software and the design syntax as well as design output are given in Appendix-I. Design output contains the D-efficiency value of the OOD design which represents the percentage of optimality of the design. Furthermore, it includes MNL efficiency measures, correlations (Pearson Product Moment), MNL covariance matrix, MNL fisher matrix and MNL choice probabilities.

The OOD design used in the first pilot had three alternatives, one status-quo and two changes, and five attributes. This design gave a set of 72 choice situations, randomly divided into 12 blocks. Six choice situations were presented to each respondent using a choice card. A choice card gave respondents a choice between three alternatives including one status-quo and two proposed changes. The example of the choice cards used in this research can be seen in Appendix-III.

b. Efficient design

As indicated above, an efficient design was adopted in this research to reduce the number of decisions per respondent. Using priors from the first pilot, D-error minimizing Bayesian experimental design was created, which was used in the second pilot. According to the Bayesian approach to constructing efficient experiments, the efficiency of a design is evaluated over draws taken from the prior parameter distributions assumed in generating the design, and Bayesian efficiency of a design is the expected value of whatever measure of efficiency is assumed over all the draws taken (Choice Metrics, 2018). This approach therefore requires the use of simulation methods to approximate the expected value for differing designs.

Due to uncertainty about the true parameter values, priors are not exact but an approximation. Hence, Bayesian efficient designs make use of random priors instead of fixed priors, described by random distributions. D-error minimizing Bayesian experimental design also had three alternatives and five attributes. The total choice situations, number of blocks, and choice situations per respondent in D-error minimizing Bayesian experimental design were identical to orthogonal design. So, each respondent was presented with six choice situations using a choice card. A choice card gave the choice to respondents between three alternatives including one status-quo and two proposed changes.

The Ngene software syntax used to create Bayesian D-efficient designs and additional design output are given in Appendix-I. Additional design output includes MNL efficiency measures, MNL covariance matrix, MNL probabilities and MNL utilities. Since when creating the Bayesian D-error over different random draws, one can choose to take different values of the efficiency measure being optimised, the design used in this research has the mean value of the efficiency measure.

Unlike an orthogonal design, more information on the model type and prior parameter values is required when dealing with the efficient designs. A conditional logit model was estimated to obtain the priors from the data gathered in the pilots. Conditional logit estimates of pilots are available in Appendix-II. Since the second pilot survey was implemented using Bayesian D-efficient designs, it helped in improving the experimental design that was used in the final survey. For example, first pilot with OOD design was used only to collect the priors to create the efficient design, however, the second pilot was implemented with the actual design which imparted information about attribute parameters and yielded data to estimate the model parameters with low standard errors.

The final surveys of the present research were administered using Bayesian D-efficient designs. The design used for the consumer survey had 72 choice situations and 12 blocks, whereas the design involved in the farmer survey had 60 choice situations and 10 blocks. So, in both surveys, each respondent faced six choice situations on choice cards. The designs used for both experiments in the final surveys were unlabelled. Thus, respondents differentiated between each alternative using the information of attributes and attribute levels.

Table 3.2: Feature of DCE choice tasks

Design type	**Orthogonal design**	**Efficient design**	
	Pilots	**Farmer survey**	**Consumer ssurvey**
Alternative label	Unlabelled	Unlabelled	Unlabelled
Priors	Collected information	MNL pilot estimates	MNL pilot estimates
Choice situations	72	72	60
Blocks	12	12	10
Choices/respondent	6	6	6
Alternatives	Two & a staus quo	Two & a staus quo	Two & a staus quo
Observations/ respondent	18	18	18

3.4.3 Questionnaire design

Developing a questionnaire is tricky, however, adequate preparation can help researchers avoid a lot of problems which they may not be able to rectify at a later stage. In this regard, questionnaire development guidelines and relevant literature were reviewed in addition to expert comments on the draft questionnaires. The types of questions that the respondents can answer are largely dependent on their level of education and other cultural and environmental factors. This was more pertinent to the farmer survey conducted with tomato farmers in a rural cultural and low literacy setting where all farmers were not educated. In addition, farmer responses were influenced by their peers as they would prefer discussing with others as communal decision making is very common in these areas.

Since the present research involved the experimental designs in addition to the questionnaires, only necessary information was included in the questionnaires. This was crucial as the DCE surveys require more effort, time, and resources and the longer questionnaires would have compromised the data quality due to longer duration of interviews, tiring effect, and response heuristics. Due to this trade-off between data quality and quantity; information regarding household assets, wealth, farm machinery, and family labor was not included in the questionnaire. This is also highlighted in the study limitations. Nonetheless, questions were included in the questionnaires very carefully while considering the following factors. For example, only necessary questions were included in the questionnaires to keep it short and focused. Similarly, it was made sure that the questions are clear and respondents could understand them. Furthermore, utmost care was taken to avoid leading questions and enumerators were trained on this as well.

Furthermore, considering the respondents' tiring effect and cognitive burden, the questionnaires' length was confined to two to three pages. As pre-testing of the survey instrument is important to collect the right data in an appropriate format, questionnaires were piloted before using those into final surveys. Both pilots included the complete interviews of 15 to 20 respondents from consumers as well as farmers. The questionnaires used in both surveys could be found in Appendix-IV.

3.4.4 Sampling strategy

The sampling frame of the present research represents the two sets of population to whom the surveys were administered. The choice of the sample population for both surveys is dependent on the objectives of this study, i.e. to investigate the farmer and consumer preferences for sustainable agriculture. Hence, the sample population for the farmer survey is tomato farmers and the sample population for the consumer survey is tomato consumers. The location of the sampling frame in this research is strategic as there are certain areas where tomatoes are produced in Pakistan. Furthermore, considering the financial constraints, it was difficult to survey more than one district.

In this regard, the district of Khushab was selected because it has dense pockets of tomato farmers, to collect the desired sample. The Khushab district has two tomato producing zones and within each zone a simple random sampling technique was used to draw the sample. The survey was started from one end of both specified areas. Each alternative household was selected though not all farm households produce tomatoes. Furthermore, some households were unwilling to participate in the survey. As a result, roughly one third of the total farm households in both the tomato producing zones in Khushab district were sampled.

The consumer survey, on the other hand, was administered in different shopping centres and weekly bazaars in Islamabad where people shop for vegetables. A stratified random sampling technique was used in consumer surveys to collect the data. This technique is suitable in this research as Islamabad is a planned city divided into sectors, and some sectors are known as high-income areas as the property value, rents and other amenities are superior to other sectors which are considered low-income areas. Hence, the city was divided into three stratums: high, middle and low income. The survey was administered using a random sampling technique in the shopping centres and weekly bazaars of respective strata. The consumers were asked for their willingness to participate in the survey.

The sample size for both surveys is 255 households, the aimed sample size was 250 and few additional interviews were conducted. Since there are DCE surveys, each respondent faces multiple choice cards.

The experimental designs used in this research had six choice cards and each choice card had three alternatives. So, there were 18 observations per respondent. Thus, the total number of observations with six choice cards and three alternatives is (255*3*6) 4,590 in each survey. Each survey had a few incomplete interviews, which were dropped from the analysis.

3.4.5 Data collection

Data collection for this research had involved the face-to-face interviews of respondents. The reason for conducting face-to-face interviews was that most of the respondents in the study areas are not well educated and need assistance in filling the survey instruments. For example, respondents had often asked for clarifications during the surveys as DCEs are more technical than simple primary surveys. Moreover, it is also not feasible to administer web surveys in study areas as there is a lack of internet infrastructure. The survey instrument included a research introduction, choice cards with text and infographics to describe the proposed changes in agrochemical use and irrigation methods, and the questionnaires. The unit of analysis for both of the surveys is the household. The surveys were administered by trained enumerators who interviewed respondents using the survey instrument.

Enumerators were trained, supervised and facilitated during the surveys. A team of female enumerators was also used in the consumer survey as female respondents hesitate giving interviews to male enumerators due to cultural norms. The farmer survey, however, does not include the female sample as the farms in rural areas of Pakistan are managed by the male family members of a household.

3.4.6 Data set-up

DCE modelling has its own data set-up requirements as the data are set-up in specific formats that vary across data analysis software packages (Hensher et al., 2005). Since the data analysis for this research is carried out using Stata software, the data format is for Stata. However, researchers can always tailor the data format for the kind of software packages they use in their data analysis. As DCE surveys involve repeated choices; a single respondent generates multiple choice observations and each choice observation involves several alternatives, and each alternative is described by a row in the data.

As a result, each respondent is identified by a serial number and so is each choice observation, which is connected with a choice-task card in the experimental design, and a serial choice number. In this case, therefore, one respondent serial number is repeated eighteen times and each choice-task card serial number is repeated three times as each experimental choice task has three alternatives. The outcome variable in this format is a binary number where ‘1’ represents the ‘choice’ of a specific alternative made by respondents in a choice situation and ‘0’ otherwise. As each choice card has three alternatives and one is chosen, one third of the total data observations of the outcome variables are '1' and remaining two thirds are '0'. Hence, the sum of the choice variable entries should be equal to 1 within each choice situation/task and equal to the number of choice cards across the total respondents (Hensher et al., 2005).

The outcome variable entry against each alternative in DCE data set-up corresponds to the code of the respective alternative in a choice card. This code is generated from experimental design software, Ngene in the present research, and is entered into the Excel spreadsheet before the final data entry. It is worth mentioning that the questionnaire data on respondents' socio-demographic characteristics are invariant across decisions provided. This means that it is entered in only one row as it comes from a single respondent irrespective of the number of choice cards and alternatives s/he faced and the resultant number of observations per respondent generated. In this research, questionnaire data on socio-demographic characteristics is copied from the first row to the rest of the seventeen rows. Hence, data on socio-demographic characteristics is the same across data observations (within one sample) but vary across individuals.

3.5 DCE data analysis

The DCE data analysis in the present research is carried out by estimating the models in preference-space and price-space. This estimation approach is adopted for both farmer and consumer data.

As Train and Weeks (2005) discuss, when discrete choice models with random coefficients are applied to estimate the distribution of consumers' willingness to pay for alternative attributes, the price coefficient is held constant. This allows the distributions of willingness to pay (WTP) to be calculated easily from the distributions of the non-price coefficients, since the two distributions take the same form[3]. The mean and standard deviation of WTP is simply the mean and standard deviation of the attribute coefficient scaled by the inverse of the price coefficient. A fixed price coefficient implies that the standard deviation of unobserved utility, known as scale parameter, is the same for all observations. However, as Louviere (2003) points out, scale parameter varies randomly over observations and ignoring this variation can cause error in results interpretation. For example, if the price coefficient is fixed when scale varies over observations, then the variation in scale will be mistakenly attributed to variation in WTP.

The present research is conducted by estimating the discrete choice models in preference-space and willingness-to-pay space. For preference-space models, a convenient distribution is specified for the coefficients and WTP is derived from the estimated distribution of coefficients, whereas for the

[3] if the coefficient of an attribute is distributed normally, then WTP for that attribute, which is the attribute's coefficient divided by the price coefficient, is also normally distributed

models in price-space, convenient distributions are specified for the WTP and the price coefficient. The two approaches are formally equivalent, in the sense that any distribution of coefficients translates into some derivable distribution of WTP's, and vice-versa. However, the two approaches differ in terms of numerical convenience under any given distributional assumptions.

A mixed logit model is estimated in both preference-space and price-space. Mixed logit models are the state-of-the-art tool applied in analysis of discrete choices data (Hole and Kolstad, 2012). This model specification accounts for heterogeneity in preferences which are unrelated to observed characteristics and it has been shown that any discrete choice random utility model can be approximated by an appropriately specified mixed logit model (McFadden and Train, 2000). The present research compares the preference- and price-space approaches to model the distribution of willingness to pay and willingness to accept using stated preference data of tomato farmers and consumers from Pakistan.

The following section discusses the model specification in preference-space and willingness-to-pay (price) space.

Following Train and Weeks (2005), this description presents two types of models. Here, decision-makers are indexed by n, choice alternatives by j, and choice situations by t. Utility is specified as separable in price, p, and non-price attributes, x.

$$U_{njt} = -\alpha_n p_{njt} + \beta'_n x_{njt} + \varepsilon_{njt} \qquad (3.8)$$

In this specification, α_n and β_n are individual-specific coefficients that vary randomly over decision-makers and ε_{njt} is i.i.d random term. This analysis assumes that ε_{njt} is distributed extreme value, though the analysis is the analogous for other distributions. The variance of ε_{njt} can vary across different decision makers: $Var\left(\varepsilon_{njt}\right) = k_n^2(\frac{\pi^2}{6})$ where $'k_n'$ is the scale parameter for a decision maker 'n'.

Although the utility specification is not yet normalized, the current formulation allows to clarify the circumstances under which the scale parameter can be expected to vary over decision-makers. A random scale parameter is conceptually different from random values for α and β. α_n and β_n represent the taste of person n, and these parameters vary over decision-makers due to variation in their tastes. However, the scale parameter does not represent a term within the utility function in any given choice situation but rather the standard deviation of utility over different choice situations. By allowing the scale parameter to be random, the researcher gives a variance to a variance. Variance of ε has two possible situations.

1) The unobserved term ε might reflect factors that are actually random from the decision-maker's perspective, rather than factors that are known to the decision-maker but unknown by the researcher. At this point, the variance of ε reflects the degree of randomness in the decision-making process, which can be expected to differ over decision-makers. Although randomness can also arise in revealed preference data, it is more prevalent in stated preference data as decision-makers have different attention to the task and in their constructs of unlisted attributes. 2) In this data set-up, each decision-maker faces a sequence of choice situations with unobserved factors varying in each choice situation. The variance of these unobserved factors over choice situations for each decision-maker is likely to be different for different decision-makers, even when the unobserved factors are known to the decision-maker and unobserved only by the researcher.

These two situations also imply that when ε represents factors that are known to the decision-maker but unknown by the researcher, and only one choice situation is observed for each decision-maker, i.e. each observation represents a different decision-maker, there is little need to allow the scale parameter to vary over decision-makers. In this situation, the scale parameter captures variance over observations in factors that the researcher does not observe which means that this variance is defined by the researcher, not the decision-maker, and takes a given (fixed) value for the researcher.

Dividing utility (3.1) by the scale parameter does not affect behavior and yet results in a new error term that has the same variance for all decision-makers.

$$U_{njt} = -(\alpha_n/k_n)p_{njt} + (\beta_n/k_n)'x_{njt} + \varepsilon_{njt} \qquad (3.9)$$

where ε_{njt} is i.i.d. type-one extreme value, with constant variance $\pi^2/6$. The utility coefficients are defined as $\lambda_n = (\alpha_n/k_n)$ and $c_n = (\beta_n/k_n)$, such that utility is written:

$$U_{njt} = -\lambda_n p_{njt} + c_n' x_{njt} + \varepsilon_{njt} \qquad (3.10)$$

As k_n enters the denominator of each coefficient, the utility coefficients are correlated if k_n varies randomly. Specifying the utility coefficients to be independent implicitly constrains the scale parameter to be constant. If the scale parameter varies and α_n and β_n are fixed, then the utility coefficients vary with perfect correlation. If the utility coefficients have correlation less than unity, then α_n and β_n are necessarily varying in addition to, or instead of, the scale parameter.

The above equation (3) is the model in preference-space where willingness to pay for an attribute is the ratio of the attribute's coefficient to the price coefficient $\omega_n = c_n/\lambda_n$. Using this definition, utility can be rewritten as,

$$U_{njt} = -\lambda_n p_{njt} + (\omega_n \lambda_n)' x_{njt} + \varepsilon_{njt} \qquad (3.11)$$

This is called the utility in price-space. This parameterization helps in distinguishing the variation in WTP, which is independent of scale, from the variation in the price coefficient that incorporates the scale. The utility expressions, however, are equivalent. Any distribution of $\lambda_n$and c_n in (3.10) implies a distribution of λ_n and ω_n in (3.4), and vice-versa. The general practice has been to specify distributions in preference space, estimate the parameters of those distributions, and derive the distributions of WTP from these estimated distributions in preference-space which is limited in implementation by the use of convenient distributions for utility coefficients. Convenient distributions for utility coefficients do not imply convenient distributions for WTP, and vice-versa.

If the price coefficient is distributed log-normal and the coefficients of non-price attributes are normal, then WTP is the ratio of a normal term to a log-normal term. Similarly, normal distributions for WTP and a log-normal for the price coefficient implies that the utility coefficients are the product of a normal term and a log-normal term. The placement of restrictions is similarly asymmetric as researchers often specify uncorrelated utility coefficients which implies that scale is constant and WTP is correlated in a particular way. Similarly, uncorrelated WTP implies a pattern of correlation in utility coefficients that is difficult to implement in preference-space. However, models' accuracy in the use of convenient distributions and restrictions in preference-space or price-space is necessarily situationally dependent as the true distributions differ in different applications.

3.6 Findings of the DCE design and conduct

This section outlines the main findings regarding the implementation of the DCEs that inform how the DCE analysis was conducted using the above detailed methodology. These findings are presented in chronological order starting from the design of the attribute table and creation of experimental design to the data analysis and writing of the results. The first step towards the implementation of the DCEs was to collect the background information and design attribute tables for both the surveys. This was achieved by collecting background information from primary and secondary sources.

This was followed by the creation of experimental designs. Two experimental designs, orthogonal and efficient design, were used in the present research. Orthogonal experimental design was employed in the first pilot to collect the priors for the efficient design, however, the priors for the orthogonal design were based on the background information that was collected using primary and secondary sources. The second pilot as well as the final surveys were implemented using D-efficient Bayesian design. The experimental designs were created using Ngene software. Ngene provided the code for experimental designs which was imported in Microsoft Excel to create the choice situations. These choice situations were used to produce the choice cards to present to the survey respondents along the questionnaires.

Visual aid such as pictures were used to create the choice cards which demonstrated the changes in attributes to enable respondents to understand the changes.

To implement the DCEs in this research survey instruments were piloted. Pilot surveys were conducted with actual respondents in study areas which helped in conducting this research in two ways. First, pilot surveys provided the priors to create the experimental designs for this research. Second, pilots were helpful in refining the survey instrument which included the choice-cards and survey questionnaires. For example, these helped in improving the visual aid and description of the attribute levels that demonstrated the changes in current agricultural practices. Similarly, pilots were useful in modifying questions in the survey questionnaires to make those easier to understand for the enumerators as well as the survey respondents.

The collected data from pilots and final surveys were entered in Microsoft Excel by the trained staff hired for the purpose of entering the survey data. Data entry staff was provided with Microsoft Excel sheets designed for the data entry for the present research, for example, the Microsoft Excel sheets had the appropriate format which could support the data analysis in Stata. After completion of data entry, data were rechecked to avoid any possible mistakes. Survey data entry management also involved data cleaning and labelling which was performed before the data analysis.

The next stage was data analysis, which was carried out using the Stata 15 data analysis software package. To analyse the DCE data for the two surveys, Stata estimation routines were developed under the supervision of the PhD advisors. The detailed code of the Stata estimation routines used in present research is available in the Appendix-V. Model estimation was carried out using two alternative approaches such as utility estimation in preference-space and utility estimation in WTP and price-space, which enabled the comparison of the two approaches, with respect to model fit and welfare estimates, using the data generated from the surveys of the present research.

The preliminary results from the data estimation as well as their interpretation were included in the second-year progression review of the. The second-year progression review is the internal review as part of the process of PhD. In addition, the results were also presented in the seminar arranged for the second-year progression review. Comments from the reviewer as well as participants were incorporated in the thesis. After revising the data estimation and incorporating more details under the supervision of PhD advisors, results of the data estimation were compiled.

After completing the results write-up, other parts of the thesis such as introduction, literature reviews, and methodology were compiled. This was followed by the thesis design and format which is very important as this thesis has three projects in addition to chapters on study area, data collection and research methodology. The last stage of this thesis was to arrange the proof reading and submit the thesis for viva examination.

This chapter (Chapter 3) of the thesis answers the fifth research question stated in the introduction chapter (Chapter 1) of this thesis regarding the design and conduct of DCEs in a developing country context, i.e. Pakistan.

The next chapter (Chapter 4) is an analysis of farmer and consumer perceptions of sustainable agricultural practices which is also the first project in this thesis.

Chapter 4 Farmer and consumer perceptions of sustainable agricultural practices

Abstract

This research investigates the farmer and consumer perceptions of different agricultural practices used in tomato cultivation in the Pakistani context. This includes the investigation of the existing agricultural practices as well as the proposed changes such as a reduction in the use of pesticides and fertilisers in tomato crop to adopt sustainable agricultural practices for cleaner tomato production. Analysis is carried out using data from two primary surveys administered to the tomato farmers in Khushab district, and the tomato consumers in Islamabad. The results reveal that majority farmers and consumers are aware that the existing agricultural practices are unfriendly for their health and the natural environment. This indicates that both farmers and consumers understand the problems with intensive farming used in tomato cultivation, and hence might be willing to consider the alternatives to agricultural intensification. Empirical results suggest that agricultural extension has the potential to play a positive role in enabling farmers to adopt sustainable agricultural practices; however, there are serious gaps in the provision of agricultural extension services. While there seems to be gaps in food safety knowledge and awareness amongst farmers as well as consumers, results suggest that there is a scope for sustainable agricultural practices and cleaner tomato production.

Key words: *Perceptions, sustainable, market-based mechanism, health- and environment-friendly*

4.1 Introduction

Recently, the topic of sustainable agriculture has received a lot of attention from consumers, policy makers and researchers as the existing agricultural practices are not health- and environment-friendly which makes agricultural production unsafe and unsustainable (Wang et al., 2019). Predominantly, this is because of a massive uptake of intensive farming that involves the concentrated use of agrochemicals such as pesticides and fertilisers. Intensive farming has become very common after the advent of modern agricultural technologies, but it has serious implications for human health and the natural environment (Elahi et al., 2019). This is a concern for the public as unsafe food causes illness which has a cost in the form of medical expenditures, forgone labour hours and inconvenience; not to mention the deaths from consuming unsafe food (Nardi et al., 2020).

Research shows that each year millions of people are poisoned in the world, particularly in the developing countries (Tariq et al., 2007), due to pesticide exposure. Pakistan is also one of those countries where agricultural pollution is a rampant problem and a serious health issue, for example, empirical evidence shows that Pakistani rice farmers face health problems due to pesticide exposure (Elahi et al., 2019). The intensive use of pesticides and fertilisers also contributes to the environmental problems such as air, water and soil pollution in Pakistan (Elahi et al., 2019). The privatization of agrochemical procurement and sale, poor enforcement of regulations and a lack of farmer education and training to apply agrochemicals are some of the factors responsible for the unchecked intensification and thereby the agricultural pollution in Pakistan (Tariq et al., 2007; Saeed et al., 2017). Research claims that about 80% of the agrochemicals sold by private companies in Pakistan are without proper safety guidelines (Elahi et al., 2019).

Nevertheless, to curb the agricultural pollution and produce health- and environment-friendly cleaner food, adoption of sustainable agricultural practices has become necessary (Crenna et al., 2019; Elahi et al., 2019). As such, the transition of the agriculture sector from conventional to sustainable farming requires more novel approaches. For example, in addition to stringent monitoring of food production systems to ensure producer compliance to the health and safety standards; policy makers also deploy the market-based mechanisms, e.g. economic incentive schemes, which incentivises producers to supply certified health- and environment-friendly cleaner food (Wang et al., 2020). This thesis also investigates farmer and consumer preferences for the uptake of sustainable agricultural practices and cleaner food production in Pakistan using the idea of market-based mechanisms. Since farmers and consumers are the two main stakeholders of this proposal, the analysis would have been incomplete without studying their perceptions. This will not only help in aligning the perceptions and preferences of both the groups, but it will also identify and uncover the gaps that need to be filled.

With this in mind, this chapter investigates the farmer and consumer perceptions of existing agricultural practices and the proposed changes (e.g. reduction is the use of agrochemicals such as pesticides and fertilisers) required for the uptake of sustainable agricultural practices in the study areas. Since farmers will adopt the sustainable agricultural practices, it is important to investigate their opinions and willingness to modify the existing agricultural practices as promoting sustainable agricultural practices without considering farmer perceptions may be ineffective (Tatlıdil et al., 2009). Similarly, understanding consumer perceptions and knowledge is also central as consumers can demand and pressurise producers to make changes in the existing food production practices which are currently unsafe (Nardi et al., 2020). Moreover, consumer perceptions and their concerns about the food quality is vital to identify the food monitoring priorities (Hartmann et al., 2018). Prior research e.g. Schröder et al. (2018) has also emphasised on employing a coupled approach to study both consumer and producer sides.

In this regard, this chapter will render a deeper understanding of how farmers and consumers see the proposed changes. For instance, the empirical analysis of the factors that explain the farmer and consumer perceptions of the proposed changes would allow policy makers to design more targeted interventions. As a result, this would increase the success of policy interventions, and guide relevant departments in efficient allocation of scarce resources which is the main contribution of this chapter in addition to providing a context and the background to the DCE analysis.

As stated above, this research investigates farmer and consumer perceptions of the existing agricultural practices, and the proposed changes to adopt the health- and environment-friendly sustainable agricultural production in the Pakistani context. Following are the specific research questions that this study attempts to answer.

4.1.1 Research questions

1. What is farmers' and consumers' perception and understanding of existing agricultural practices and proposed changes in the tomato crop cultivation in Khushab, Pakistan?
2. What are the factors that determine farmers' and consumers' perceptions with regards to current agricultural practices and the proposed changes to adopt sustainable agriculture?

The remaining chapter is presented as follows: section 4.2 presents the literature review, section 4.3 describes the material and methods of this research, section 4.4 discusses the results, while section 4.5 presents the conclusion and policy implications.

4.2 Literature review

This section presents the review of the relevant literature which includes a selection of empirical studies on farmer and consumer perceptions, awareness, attitude and knowledge with regards to sustainable agricultural practices. The studies selected for this review are not only directly relevant to the theme of the present research, but also explore multiple dimensions of sustainable agricultural practices in developed and developing countries.

There are several social, economic, and demographic factors that drive the farmer and consumer perceptions and practices of sustainable agriculture. For example, access to financial resources (Pilarov et al., 2018), non-farm employment and environmental concern (Zhang et al., 2018), age, education, awareness and knowledge of sustainable agriculture (Tatlıdil et al. 2009; Sadati et al., 2010; Kabir and Rainis, 2015; Fisher et al. 2018), role of agricultural extension (Tatlıdil et al. 2009; Sadati et al., 2010; Kabir and Rainis, 2012; Kabir and Rainis, 2015), farmer past experience (Petway et al., 2019) ownership of land (Tatlıdil et al. 2009; Kabir and Rainis, 2015) and cultivation area (Kabir and Rainis, 2015; Vidogbe´na et al. 2016) mainly explain the farmer perceptions and practices.

Nevertheless, farmers lack the knowledge of various aspects of sustainable agricultural practices such as soil fertility and soil erosion control benefits of legumes (Kiełbasa et al., 2018; Muoni et al. 2019) can impede their understanding and thereby the uptake of sustainable agricultural practices. Empirical evidence shows that farmer perceptions of agrochemical risk to human health and the natural environment are vital to their uptake of sustainable agricultural practices (Ntow et al., 2006; Pilarov et al., 2018). Furthermore, farmer risk perceptions are affected by farming experience, education and training of farmers (Kabir and Rainis, 2012).

On the other hand, the main drivers of consumer perceptions and choices regarding sustainable agriculture and cleaner food are food expenditure, presence of children in household, food safety awareness, nutritional health, packaging, label trust, and online shopping experience (Zhang et al., 2018); news reporting and consumer social network (Zhen et al., 2019); consumer trust on food and food certification (Niyongira 2017; Kendall et al. 2019; Wang et al. 2020); age, education, and income (My et al., 2017; Liu and Niyongira, 2017); and communication of pro-environmental beliefs (Wong et al., 2020).

Research shows that with the increase in awareness about food quality; consumers have indicated their preference towards more organic, local and more natural foods (Zhang et al., 2018; Martins et al, 2019; Fibri and Frøst, 2019). Likewise, consumers who are older, have a higher education and a higher family income have bought organic vegetables more frequently (Roitner-Schobesberger et al., 2008). Nevertheless, empirical evidence indicated significant gaps in consumer food safety knowledge and awareness (Badrie et al., 2006; Ergönül 2013).

In contrast to previous research which has examined farmer and consumer perceptions, this research not only deploys a coupled approach to compare the farmer and consumer perceptions, but the empirical analysis of the factors affecting farmer and consumer perceptions is also informed by the heterogeneity in farmer and consumer perceptions which was uncovered in descriptive analysis and warranted for further investigation.

Next section presents the data and methodology used in this study.

4.3 Material and methods[4]

This research is carried out using primary data collected through the surveys administered to tomato farmers and consumers in study areas. Data analysis in this research is carried out using descriptive as well as econometric analysis. The descriptive analysis presents the respondent perceptions and other relevant information in the form of tables and graphs, whereas the econometric part investigates the socio-demographic factors that affect the farmer and consumer perceptions with regards to the proposed changes required to implement sustainable agriculture. Below are the details of the material and methods used in this research.

4.3.1 Methodology design

This research is designed in the light of previous literature that has examined perceptions and practices with regards to different food production methods, especially sustainable agriculture. From methodological point of view, several studies e.g. Kabir and Rainis (2012), Kabir and Rainis (2015), Fisher et al. (2018), and Vidogbe´na et al. (2016) have used similar approaches to investigate respondents' perceptions and practices with regards to sustainable agriculture. For example, these studies explore socioeconomic phenomena that explain different perceptions and practices. However, the theoretical foundations and the methodology of the present research are inspired by Zhang et al. (2018) and Pilarov et al. (2018) studies which investigate similar research questions and deploy comparable empirical techniques.

4.3.2 Econometric analysis

The econometric approach deployed in this research estimates the extent to which various socio-demographic factors explain the perceptions of survey participants. The dependent variables used in this study are context specific. For example, dependent variables used in the farmer data analysis denote farmer perceptions of the impact of the proposed changes on the tomato crop and tomato farm gate price, whereas the dependent variables used in the consumer data analysis characterise consumer awareness and understanding of different farming practices.

The selection of explanatory variables for regression analysis carried out in this chapter is made in the light of previous literature that has investigated similar issues e.g. Kabir and Rainis (2015), Vidogbe´na

[4] The description of study site and data collection is given in Chapter 2 and 3.

et al. (2016), Fisher et al. (2018), Pilarov et al. (2018), Zhang et al. (2018), and Zhen et al. (2019). Farmer data regressions include household socio-demographic characteristics, farming related information, institutional features and respondents' perceptions and awareness; while consumer data regressions take-in consumer socio-demographic characteristics, consumer information and understanding of the cleaner food and their health and food consciousness. The summary statistics of the variables used in regressions analyses are presented after this section. Prior to estimating the final econometric equations in both datasets, the selected variables were tested for collinearity. The reported results include the estimates of meaningful and significant variables.

The econometric analysis is carried out using a binary probit regression technique, which is an appropriate technique for the dichotomous choice dependent variables. Binary probit regression offers a convenient functional form for estimating a probability model with an observed dependent variable of 1/0 form which is the outcome of a binomial process. Probit regression is deployed by assuming that respondents either maintain a perception of some farming practice or not and respondents' perception of the different farming practices are determined by their socio-demographic characteristics. These socio-demographic characteristics act as proxies for economic behaviour as well as various economic constraints that agents face. Therefore, respondents' perceptions of different farming practices are analysed using a binary variable $'Y'$ consisting of two outcomes:

$$Y = \begin{cases} 1 \ if \ \text{a respodent has an opinion or underdtanding} \\ 0 \ \ otherwise \end{cases}$$

It is assumed that respondents' perceptions of different farming practices are a function of vector x_i of observable factors that determine their perception with β as a parameter vector and an unobserved random error term ε_i with '0' mean and constant variance for the categorical outcomes of the dependent variables. Results are interpreted using parameter vector that represent the marginal contributions of the explanatory variables to the marginal propensities of the outcome variables. The general model specification is given below in (4.1).

$$Y_i = \beta' x_i + \varepsilon_i \qquad (4.1)$$

Here the probability of having a perception is

$$Pr(y_i = 1|x) = Pr(y_i > 0|x) \qquad (4.2)$$

While the probability of not having is

$$Pr(y_i = 0|x) = 1 - Pr(y_i = 1|x) \qquad (4.3)$$

By Substituting (4.1) into (4.2)

$$= Pr(\beta' x_i + \varepsilon_i > 0|x) \qquad (4.4)$$

$$= Pr(\varepsilon_i > -\beta' x_i | x) \quad (4.5)$$

$$= 1 - F(-\beta' x_i | x) \quad (4.6)$$

As the error term is assumed to be independently a normally distributed

$$Pr(y_i = 1|x) = 1 - \Phi\left(\frac{-\beta' x_i}{\sigma}, \sigma = 1\right) \quad (4.7)$$

$$= \Phi(\beta' x_i) \quad (4.8)$$

Keeping other things constant, a unit change in $'x'$ we expect the probit to change by $'\beta'$. This change is estimated using the marginal effect that is defined by the following equation.

$$Average\ marginal\ effect\ of\ variable\ k = \frac{\partial Pr(y_i = 1|x)}{\partial x_k} = \beta_k \varphi(\beta' x_i) \quad (4.9)$$

The next section presents the description and summary statistics of the variables used in the empirical analysis of this chapter.

4.3.3 Description and summary statistics of the regression variables

This section presents the description and summary statistics of the key variables used in regression analysis for both farmer and consumer survey data. Table 4.1 shows the summary statistics of the key variables used in the farmer estimates. *Farmer age* is the average age of tomato farmers who participated in the survey which is roughly 40 years. *Farmer education* is the average number of years of schooling that farmers' have attained. Data shows that on average farmers have primary schooling. *Farming experience* represents the average number of years a farmer has spent farming, which is almost 22 years, showing that farmers have significant farming experience. *Farm size* is the average size of total cultivable land in acres used to grow the crops including tomatoes, which is roughly 16 acres in the study areas. *Farm ownership* is a dummy which means if a farm is being owned by the farmer who is doing cultivation, and data shows that almost 27 percent farms are cultivated by tenants.

On-farm income is the average household income of a farmer (in Pakistani rupees) from crops in one crop season. *Off-farm income* is the average household income of a farmer (in Pakistani rupees) that is generated from activities other than farming. This mainly includes income from off-farm labour and small businesses. *Agrochemical use training* is a dummy variable which shows if a farmer has received any training/advice from local agricultural extension regarding the application of fertilisers and pesticides. *Disease outbreak* refers to the average number of times a farmer has experienced a major pest or weed outbreak in the past 5 years. Data shows that on average a farm household has experienced roughly two disease outbreaks in the past 5 years in tomato crop.

Table 4.1: Summary statistics of the variables used in farmer survey regressions

Variable	Variable type	Mean	SD	Min.	Max.
Farmer age (years)	Continuous	40.09	13.71	17	75
Farmer education (years)	Continuous	6.61	3.96	0	22
Farming experience (years)	Continuous	22.02	13.11	1.5	60
Farm size (acres)	Continuous	16.04	40.55	1	400
Farm ownership	Categorical	0.73	0.44	0	1
On-farm income (PKRs)	Continuous	233828.1	216670.9	10000	1500000
Off-farm income (PKRs)	Continuous	10191.41	25959.97	0	300000
On-farm work	Continuous	3.66	3.22	0	20
Agrochemical use training	Categorical	0.16	0.367	0	1
Disease outbreak	Continuous	1.87	1.25	0	5
Market distance (km)	Continuous	17.71	24.32	0.3	200
Price reduction with 33% lower pest.	Continuous	39.80	91.02	0	850
Tomato crop area	Continuous	5.38	11.11	2	150
Tomato yield (mounds)	Continuous	449.07	717.66	0	7225
Tomato farm gate price (PKRs)	Continuous	779.08	720.88	100	7000

Market distance is the average distance (in kilometres) between a farm and the nearest market, which is roughly 18 kilometres. *Price reduction with 33% lower pesticides use* is the average tomato price reduction (Rupees/mound) a farmer expects if pesticides use is reduced by 33%. *Tomato crop area* is the cultivable land used for tomato cultivation, the average of which is five acres. *Tomato yield* is the average yield of tomato crop per crop cycle in mounds. *Tomato farm gate price* is the average farm gate price (in Pakistani rupees) of tomatoes for one mound.

Table 4.2: Summary statistics of the variables used in consumer survey regressions

Variable	Variable type	Mean	SD	Min.	Max.
Age (years)	Continuous	36.60	10.74	18	72
Gender	Categorical	0.31	0. 46	0	1
Education (years)	Continuous	15.75	2.31	8	22
Tomato consumption (kg)	Continuous	2.87	1.60	0	10
Organic understanding	Categorical	0.61	0.48	0	1
Positive health perception	Categorical	0.89	0.30	0	1
Read ingredients/nutrition facts	Categorical	0.88	0.32	0	1
Agrochemical use awareness	Categorical	0.49	0.50	0	1
Food adulteration news	Continuous	37.14	42.14	0	300
Willingness to pay	Continuous	15.63	9.04	0	50
No. of children	Continuous	1.58	1.72	0	15[5]

Table 4.2 presents the summary statistics of the key variables used in the consumer estimates. *Age* is the average age of the respondents in the consumer survey which is roughly 37 years that shows that on average consumer survey respondents were young people. *Gender* variable represents the gender distribution of the consumer survey respondents, and roughly 31 percent are male respondents. *Education* is the number of years of schooling of a survey respondent, the average of which is roughly

[5] Larger number of children is due to the joint family system in some of the households in Pakistan.

16 years which means that the majority of the survey respondents possess a college degree. *Tomato consumption* represents the per week average consumption of tomatoes in kilograms by a household in a survey sample.

Organic understanding is a dummy that refers to the consumer understanding of organic vegetables which was assessed by asking the survey participants if they could explain the meaning of organic vegetables in their own words. *Positive health perception* is also a dummy variable that shows if consumer survey participants maintain a positive perception of their current state of health or not. *Read ingredients/nutrition facts* is a dummy representing consumers who read the ingredients/nutrition facts on food labels. *Agrochemical use awareness* dummy refers to the consumers who know that considerable amounts of fertilisers and pesticides are used in growing tomatoes. *Food adulteration news* is the average number of times a respondent came across any news related to food adulteration in the last year. *Willingness to pay* refers to the average amount (in Pakistani rupees) per kilogram a consumer is willing to pay for tomatoes produced with the proposed reductions in the use of agrochemicals. *No. of children* is a variable which shows the average number of children in a consumer household who participated in the survey.

The next section presents a detailed discussion on the results of this research.

4.4 Results

The results presented in this section are the outcome of the analysis of farmers' and consumers' perceptions with regards to the current agricultural practices and the proposed changes to adopt sustainable agriculture, among other things. Below is the description of farmer survey sample characteristics.

4.4.1 Farmer sample characteristics

As explained in the research methodology, the sample of farmer survey of this study was drawn from the tomato farmers' community in Khushab district, Pakistan. The average age of a farmer in study areas is 40 years, whereas the average education is six years (Table 4.3). While most of the farmers have very low literacy, there are few of them with relatively high education. However, the mean of the 'maximum education' of farm households is nine years. The reason for recording 'maximum education' is that quite often the education of a household head is lower than the education of younger household members in rural areas of Pakistan. However, this influences household decision-making. The survey data also confirms this contention, i.e. the data on 'maximum years of education' have more observations with 10 year and above education (see Figures 4.1 and 4.2).

This is because of improvement in educational infrastructure over time, which leads to an increased access to education for younger generations in rural Pakistan. The average of farm income (net) for one season is 233,828 Pakistani rupees (USD 1,475.77 at 09/07/2019). However, there is a significant variation in reported farm income as a fraction of the sample shows a higher seasonal income from farming (see Figure 4.3). This is probably due to the disparity in farm size in the study areas as farm size data is extremely skewed (Figure 4.4). For example, the average farm size is 16 acres, but the maximum farm size is 400 acres, which is exceptionally large compared to the average.

Table 4.3: Farmers' socio-demographic characteristics

Characteristics	Mean	St. Dev.	Min.	Max.
Age (years)	40.09	13.71	17	75
Household head education (years)	6.61	3.97	0	22
Maximum education (years)	9.32	3.98	0	22
Farm income (PKRs)	233,828	216,671	100,00	1,500,000
Household size	7.23	3.19	2	22
Farming experience (years)	22.02	13.12	1.5	60
Household members working on farm	3.67	3.23	0	20
Farm size (acres)	16.04	40.55	1	400
Farmer ownership	0.73	0.44	0	1

Figure 4.1: Household head education (years)

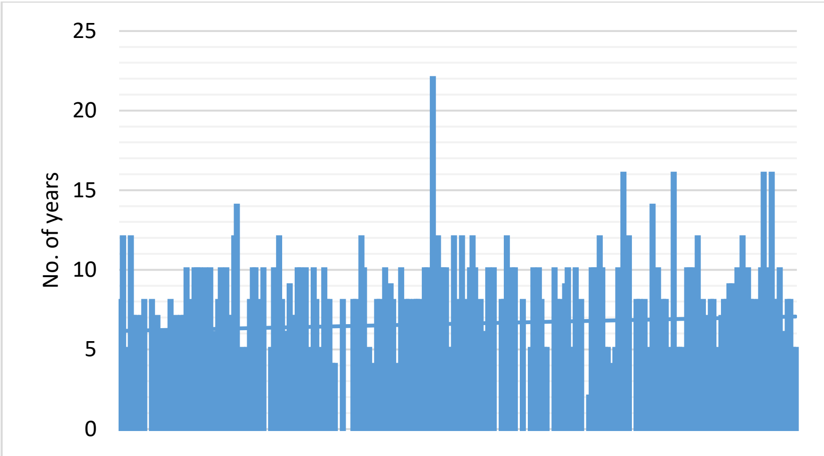
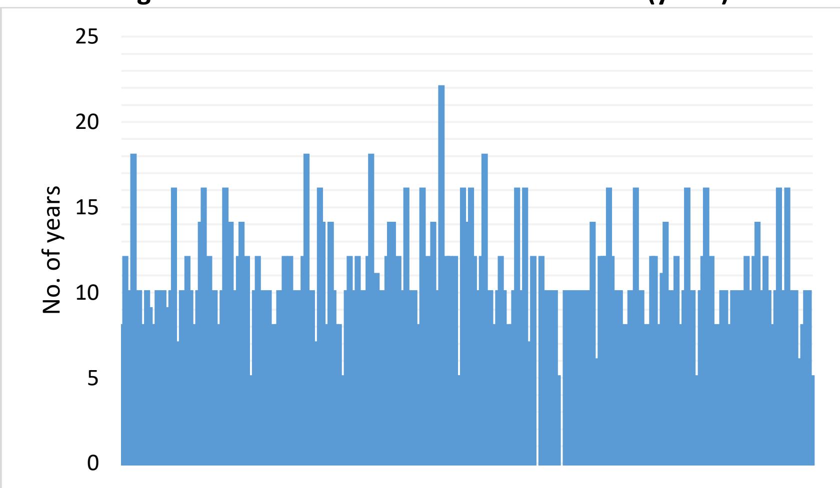
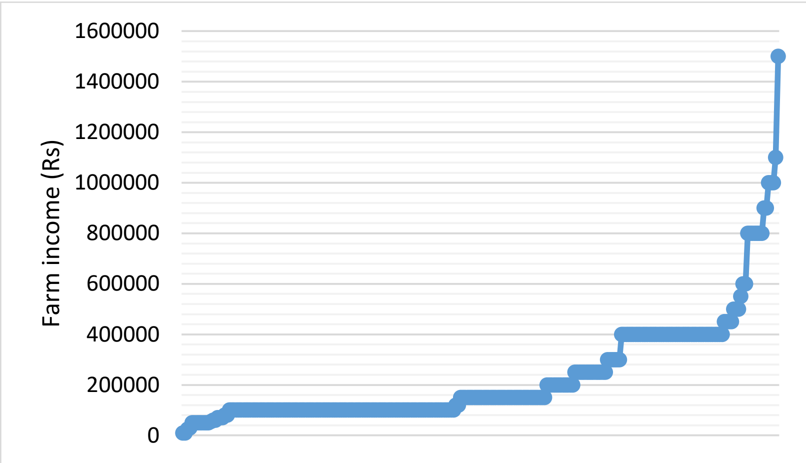


Figure 4.2: Household maximum education (years)



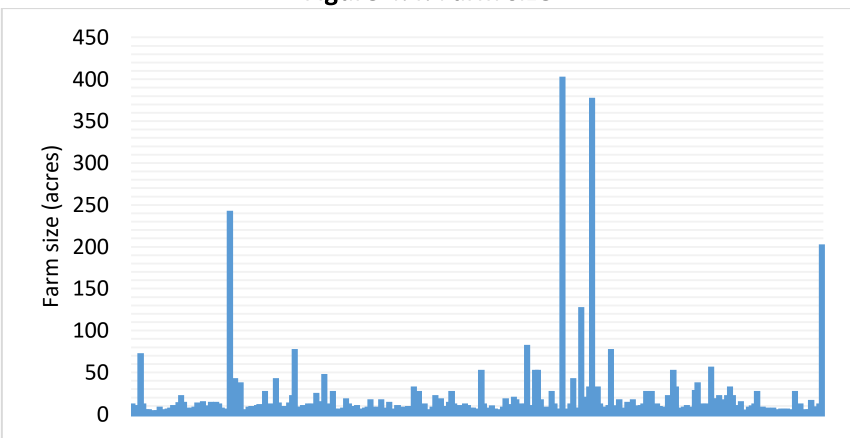
This is expected in the rural areas of Pakistan as it is a feudal society and land ownership is a symbol of prestige and power in the community in addition to a source of revenue from crops. Large farmers give land to tenants for farming in addition to employing unskilled rural labour, which also reinforces their social standing. However, the inequitable land distribution in Pakistan is also due to a lack of appropriate implementation of land reforms as political influence of landlords and weak enforcement by the government impeded the implementation. Roughly 73% of the farmers participated in the survey own the farms and remaining 27% are tenants.

Figure 4.3: Farm income (Rs.)



The average household size in this sample is seven, which is in line with the household size of Khushab district reported in the 2017 Census of Pakistan. Data shows that on average three household members work on farms in the study areas; which is common in rural areas of Pakistan due to large household size, agriculture being the main source of livelihood, and use of family labor in farming. The average farming experience in the study sample is 21 years, indicating significant farming experience of the study participants.

Figure 4.4: Farm size



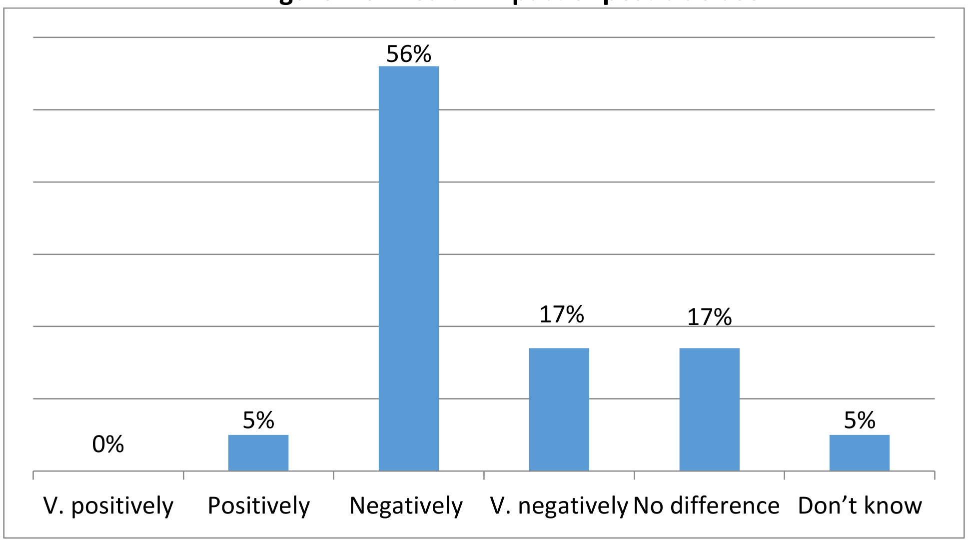
The next section discusses the farmer perceptions of the current agricultural practices and the proposed changes required for sustainable agricultural practices.

4.4.2 Farmer perceptions of health and environmental impacts of agrochemical use

This research proposes to reduce the intensive use of agrochemicals which are harmful for human health and the natural environment. Hence, it is vital to investigate farmer perceptions of the impacts of agrochemical use. In this regard, the following sections present farmer perceptions regarding the impacts of pesticide and fertiliser use on human health and the natural environment. The following question(s) were asked in the survey questionnaire to reveal farmer perceptions: "*How do the pesticides (and fertilisers) applied to your tomatoes affect your health (and the environment)?*" with the options being "*1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know*". The above statement combines four questions Q.no: 26, 27, 35 and 36 in the farmer survey questionnaire attached in appendix-IV.

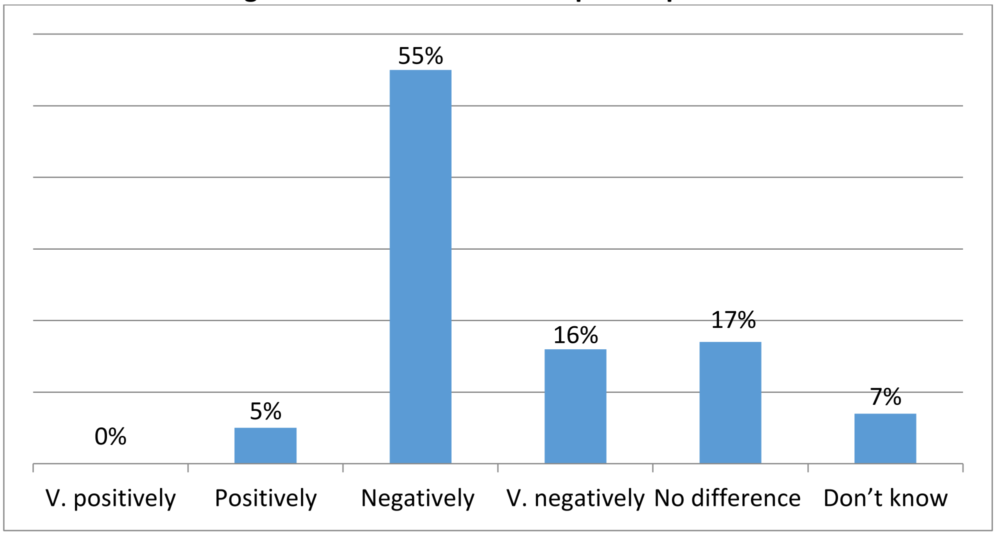
Figure 4.5 shows the distribution of farmer perceptions regarding the impact of pesticide use on their health. Almost 73 percent of the survey respondents believed that the pesticides that they use in their tomato crop have a negative impact on their health, showing farmer awareness of the health impacts of pesticides. However, not all farmers were cognisant of the health impacts of pesticide use as nearly 17 percent of them believed that pesticide use makes no difference, and some five percent farmers were unaware of the potential impacts of pesticide use on their health. Nevertheless, this is expected considering their low literacy and education and a lack of formal training to apply pesticides.

Figure 4.5: Health impact of pesticide use



Farmer responses regarding the impact of pesticide use on the natural environment (Figure 4.6) show that about 71 percent farmers consider pesticide use as harmful for the environment. These results are in line with Kabir and Rainis (2012) study. Again, nearly 17 percent farmers believed that pesticide use makes no difference, and about seven percent farmers were unaware of the pesticide impacts on the environment. This means that farmers retain almost the same level of information and awareness about the impacts of pesticides use on human health and the environment. Furthermore, farmers' perceived risk from pesticides is the same for human health and the natural environment.

Figure 4.6: Environmental impact of pesticide use



Farmer opinions regarding the impact of fertiliser use on human health demonstrate that roughly 68% farmers think that fertilisers used in tomato crop are harmful for their health (Figure 4.7). This percentage is slightly lower than that for the pesticides, which means that farmers' perception of risk to health from pesticides and fertilisers are not very clear.

Figure 4.7: Health impact of fertiliser use

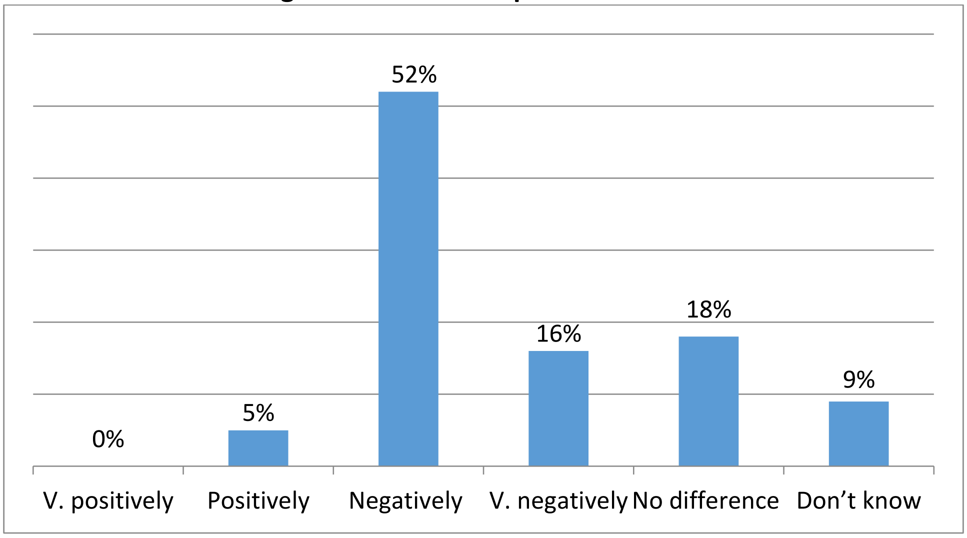
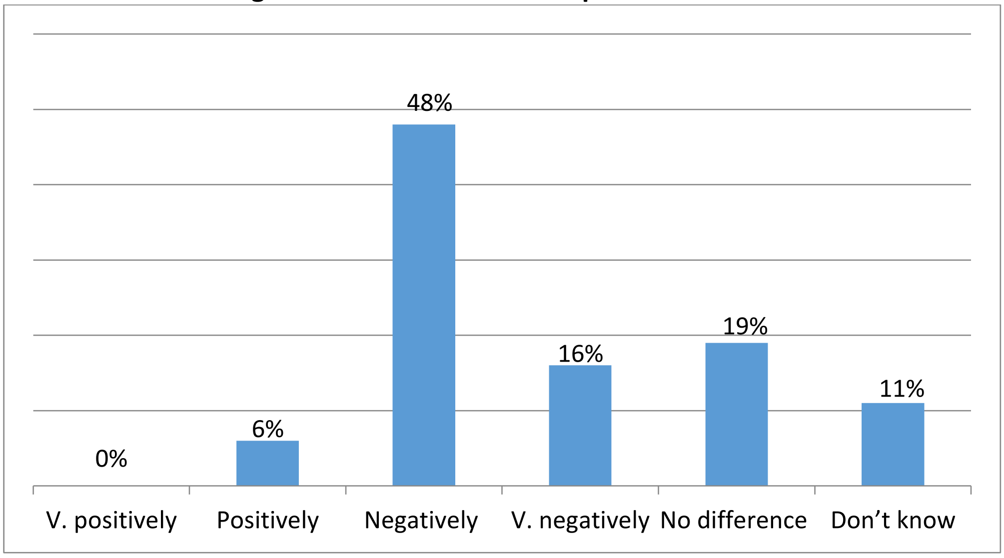


Figure 4.8 shows farmer perceptions about the impact of fertiliser use on the natural environment. Although farmer responses are not very different about fertiliser use impact on the natural environment than those for the human health, the concentrated use of fertilisers is more problematic for the natural environment as it contributes to diffuse pollution from land use activities including farming and results into water and soil pollution, causing subsequent problems for aquatic life.

Furthermore, the overuse of fertilisers also has negative consequences for the soil fertility in the longer run.

Figure 4.8: Environmental impact of fertiliser use



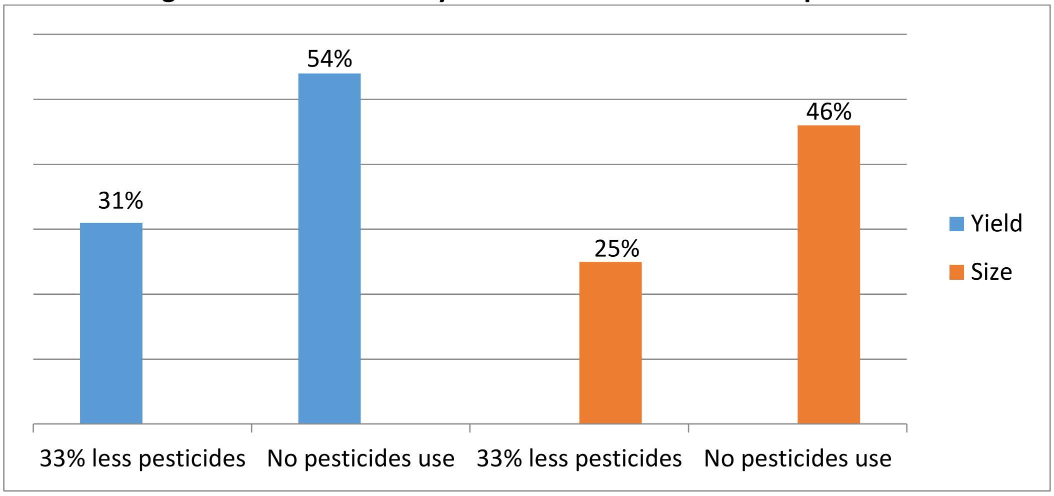
Findings presented in section 4.4.2 show that majority farmers are cognisant of the harmful impacts of agrochemical use for their health and the natural environment. This is encouraging, considering the study area comprises rural villages with low literacy and education. This suggests that at least farmers understand that there is a problem with the existing farming practices used in tomato cultivation. *These results answer one part of the first research question of the present research (i.e. farmer perceptions of the existing agricultural practices used in tomato crop) which is outlined in the introduction chapter (Chapter 1)*.

4.4.3 Farmer perceptions of the impact of proposed changes on tomato crop

The main thrust of this research is to investigate citizens' preferences for the proposed changes in current agricultural practices used in tomato cultivation to adopt sustainable agriculture. However, as farmers implement the proposed changes to adopt sustainable agriculture, it is important to examine their perceptions of these changes. Hence, farmers were asked about the impacts of proposed changes on their tomato crop. Following question(s) were used for this purpose. *"What would be the approximate decline in yield/acre (mound) ________ and average fruit size (%) of tomato ________if all pesticides/fertilisers are reduced by 33%?"* The above statement combines four questions: Q.no: 23, 24, 32 and 33 included in the farmer survey questionnaire attached in appendix-IV.

Data on farmer perceptions regarding the impacts of proposed changes on tomato crop show that (Figure 4.9) farmers perceive almost equivalent reduction in tomato yield (31%) as a result of one third reduction in the use of pesticides. However, interestingly, farmers think that complete elimination of pesticides would result in only 54% decrease in tomato yield. This means that while farmers consider the use of pesticides crucial for the tomato crop, they do not think that complete elimination of pesticides would result in crop failure. This is a positive result as far as the implementation of proposed changes, and hence the adoption of sustainable agricultural practices are concerned.

Figure 4.9: Reduction in yield and fruit size with lower pesticide use



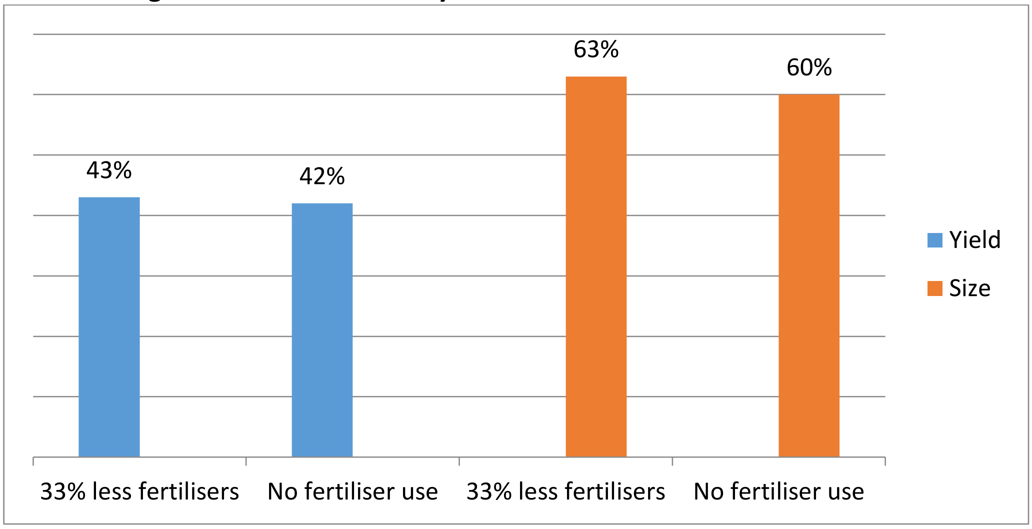
However, data shows that farmers perceive slightly lower impact of pesticide use reduction on fruit size of the tomato crop as their perceived decline in fruit size is 25% for one third reduction in all pesticides, and 46% for complete elimination of the pesticides. This is possibly because farmers use pesticides to avoid the risk of disease outbreak and/or mitigate the impact if a disease outbreak occurs.

Farmer perceived impact of fertiliser reductions on tomato crop yield (Figure 4.10) shows that farmers perceive almost 43% decline in tomato yield with one-third reduction in the fertiliser use; whereas, farmers' perceived decline in yield is 42% for complete elimination of fertilisers. The perceived decline in tomato crop yield due to one-third fertiliser reductions is more than that for one-third reduction in pesticides, which is expected as fertilisers are used to increase the crop yield.

However, farmers' perceived decline in yield with no fertiliser use is significantly lower than that of total elimination of pesticide use. This is an interesting finding which implies that farmers perceive more risk from complete elimination of pesticides as disease outbreaks can destroy the crop if no pesticides are applied at all. Another explanation is that farmers in study areas also use manure, which, to some extent, is a substitute of fertilisers.

Again, farmers perceive a relatively higher decline in tomato fruit size with one-third reduction and complete removal of the fertiliser use, which is an expected result as fertiliser use has a significant impact on fruit size of the vegetables. However, surprisingly, farmers see almost equal decline in tomato crop yield with one-third reduction as well as complete elimination of fertilisers' use. Similarly, farmers' perceived decline in fruit size is slightly higher for one third reductions in fertilisers compared to the case when there is no fertiliser use at all, which is an unexpected result.

Figure 4.10: Reduction in yield and fruit size with lower fertiliser use



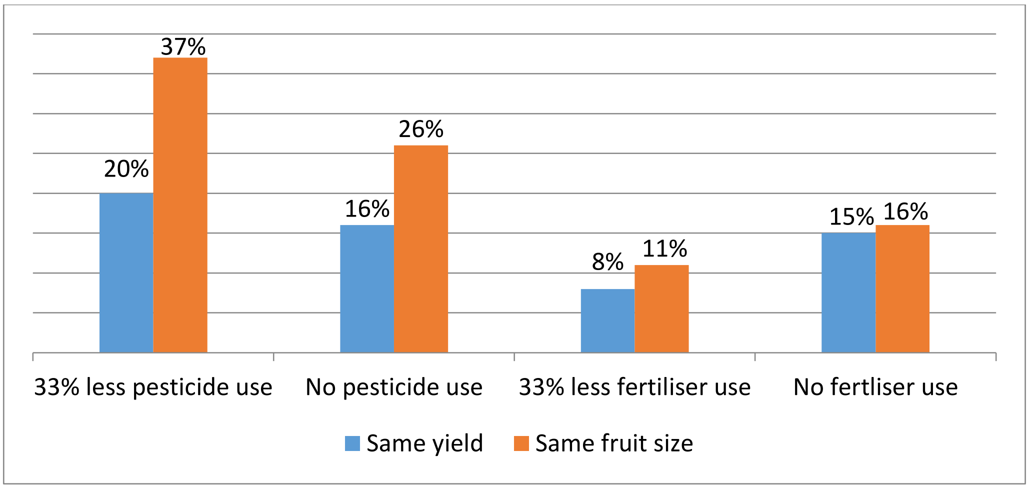
While majority farmers in the study areas think that the proposed reductions in the use of agrochemicals will have a negative impact on the output of tomato crop in terms of reduction in the yield and fruit size of tomatoes, a fraction of them maintain that the yield and fruit size of the tomato crop will remain the same. Below is the description of this variation in farmer perceptions in more detail.

4.4.4 Same yield and fruit size with the proposed changes

About 20% farmers who participated in the survey believe that the yield of their tomato crop would remain the same with one-third reduction in the use of all pesticides (Figure 4.11). Similarly, some 16% farmers think that complete elimination of the pesticides would not result in the decline in tomato crop yield at all. Moreover, while 37% farmers consider that the fruit size of their tomatoes would remain same with one-third reduction in the use of all pesticides, 26% think that the complete elimination of all pesticides will be undisruptive to the fruit size of tomatoes. As respondents often stated during the survey, this is possible if there is no disease outbreak.

Nevertheless, the fraction of respondents which maintain that the tomato yield and fruit size would remain same with the proposed reductions in the use of fertilisers is comparatively small. The important aspect of these results however is that they reveal significant heterogeneity in farmer perceptions regarding the reductions in tomato crop yield and fruit size if proposed changes are implemented.

Figure 4.11: Perceptions of the same yield and fruit size



These findings address the first research question of this thesis (outlined in Chapter 1) that examines farmer perceptions of the proposed changes in tomato crop to adopt sustainable agriculture.

The above presented results could render useful policy implications for the implementation of the proposed changes. Therefore, it is vital to conduct further investigation of the heterogeneity in farmer preferences. For this purpose, probit regression technique is deployed in the following section to examine the factors that affect farmer perceptions of the same level of yield and fruit size with the one-third reduction and complete elimination of pesticides and fertilisers.

4.4.5 Factors affecting farmer perception of same yield and fruit size

Probit regression is used to investigate the factors that explain farmers' unique set of perceptions, i.e. the tomato crop yield and fruit size would remain same despite reduction in the agrochemical use. Regression estimates in Table 4.4 (Model 1 to 4) are for pesticide reductions. The dependent variables are dummies with the value of '1' if a farmer believes that the crop yield and fruit size would remain same with lower pesticides application, and '0' otherwise. All reported regressions are statistically significant in terms of the likelihood ratio[6] (LR) statistic, which shows the overall fit of the estimated models.

Model 1 and 2 investigate the factors that explain farmer perceptions of same yield and fruit size of tomato crop with one-third reductions in the use of all pesticides. However, Model 3 and 4 examine farmer perceptions of same yield and fruit size under complete elimination of pesticides. Model 1 estimates reveal that farm size, farm ownership, disease outbreak, tomato price reduction with one-third lower pesticide use, farmer training to apply agrochemicals, and off-farm work are significant variables (Table 4.4). Farm size is significant with a negative sign, implying that farmers with relatively large farm size are less likely to perceive that one-third reduction in pesticides would be benign to the

[6] The likelihood ratio tests the null hypothesis that all the slope coefficients are simultaneously equal to zero and follows a chi square distribution with degrees of freedom equal to the number of explanatory variables.

tomato crop yield. Since large farmers make greater investment and deploy more resources in their farms, it is likely that they have a higher perceived risk of disease outbreak. Furthermore, large farmers in rural areas of Pakistan often compete with their peers on crop yield, hence they might not want to reduce the agricultural inputs. This is in accord with Zhang et al. (2018) study which shows that large farmers are less likely to reduce pesticides. However, Akhtar et al. (2018) study notes that large farmers tend to take more risks compared to smallholders.

Farm ownership is significant with a positive sign, and average marginal effects (Table 4.5) show that farm owners are 19 percent more likely to believe that tomato crop yield would remain the same with one third reduction in pesticides. The most plausible interpretation of this is that farm owners do not have to pay the land rent which gives them more liberty and confidence to try different farming practices. In addition, they usually have multiple sources of income which provide them a buffer to take the risk of reducing the pesticides. This result is in line with previous research, for example, Tatlıdil et al. (2009), Kabir and Rainis (2015), Vidogbe´na et al. (2016) and Nave et al. (2018) show that farm ownership has a positive relation with the adoption of sustainable agricultural practices. The policy implication of this result is that farm owners might be willing to adopt the proposed changes in existing agricultural practices.

Disease outbreak has an expected negative coefficient, which indicates that farmers who have experienced a greater number of major disease outbreaks in their tomato crop are less likely to believe that one-third reduction in pesticides' use would be harmless to tomato crop yield. In fact, each additional outbreak experienced by farmers in the past five years reduces their likelihood to perceive the same crop yield by almost six percent. This result implies that farmer perceptions are significantly shaped by their past experience, which is understandable considering farmers' relatively low education in study areas. This is in line with Suit-B et al. (2020) research that indicates that negative past experiences with disease outbreaks made farmers more careful to avoid reliving negative past experiences. Similarly, perceived tomato price reductions with lower use of pesticides is also significant with a negative sign, as expected. This implies that farmers who have perceived a greater decrease in tomato price with one third reductions in the use of pesticides are less likely to believe that pesticide reductions would be undisruptive to the tomato crop yield.

While only 16 percent farmers have received the training to apply agrochemicals in the tomato crop, this variable has a positive coefficient, indicating that farmers who have received the training to apply agrochemicals are more likely to perceive that one-third reductions in the use of pesticides are harmless to the tomato crop yield. Interestingly, each training enhances the likelihood that farmers perceive one-third reductions as harmless by almost 13 percent. Conceivably, this is because farmers are aware that the existing agricultural practices involve the concentrated use of agrochemicals which are harmful for human health and the environment. This conforms to Vidogbe´na et al. (2016) study which reports positive influence of farmer knowledge towards the adoption of eco-friendly. Similar results have been reported by Kabir and Rainis (2012), Kabir and Rainis (2015), Fisher et al. (2018) and Nave et al. (2018) studies; however, the present research uses agrochemicals use trainings rather than a general contact with extensions services.

Table 4.4: Factors affecting farmer perceptions of the same yield and fruit size

Variables	33% pesticide reductions		No pesticide use	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Farmer age	-0.004	-0.004	0.013*	0.011*
	(0.008)	(0.007)	(0.008)	(0.006)
Farmer education	0.028	0.044**	-0.027	0.001
	(0.027)	(0.022)	(0.025)	(0.021)
Farm size	-0.028***	-0.014**	-0.015*	-
	(0.011)	(0.006)	(0.008)	-
Farm ownership	0.851***	0.503**	0.622**	-
	(0.274)	(0.207)	(0.287)	-
Disease outbreak	-0.281***	-0.138**	-0.352***	-0.172**
	(0.091)	(0.070)	(0.097)	(0.074)
Price reduction with 33% lower pest.	-0.011***	-0.011***	-0.009**	-0.008**
	(0.004)	(0.003)	(0.004)	(0.004)
Agrochemical use training	0.603**	0.468**	-	-
	(0.260)	(0.238)	-	-
On-farm work	-0.115***	-	-	0.048*
	(0.043)	-	-	(0.027)
Market distance	-	-0.011***	-	-
	-	(0.004)	-	-
Off-farm income	-	-	-1.33e-05*	-
	-	-	(7.39e-06)	-
Tomato crop area	-	-	0.046**	-
	-	-	(0.020)	-
Tomato yield	-	-	-0.001**	-
	-	-	(.0003)	-
Tomato farm gate price	-	-	-	-0.0004*
	-	-	-	(0.0002)
Constant	-0.237	0.018	-0.767*	-0.474
	(0.457)	(0.365)	(0.455)	(0.391)
LR chi-square	52.67	44.68	46.43	23.27
Pseudo-R2	0.21	0.13	0.21	0.07
Log-likelihood	-100.08	-145.96	-87.56	-134.48
Observations	256	256	256	256

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This implies that despite farmers' limited use and/or access, agricultural extension plays a vital role in educating farmers about the appropriate use of agricultural inputs. This is an important finding with clear policy implications regarding the role of effective agricultural extension services which can facilitate the farming transition towards sustainable agricultural practices in Pakistan. Hence, the relevant departments should strive to enhance the efficiency as well as the outreach of the agricultural extension services. Moreover, agricultural extension services can neutralize the de-facto role of pesticide companies in Pakistani agriculture which include their direct interaction with farming communities to advocate the concentrated use of their products and advise them in favour of intensive farming, as indicated by Elahi et al. (2019).

On-farm work is significant with a negative sign, indicating that farm households with a greater number of members working on-farm are less likely to consider one-third reduction in the use of pesticides as undisruptive. The possible explanation of this result is that these farm households have a higher opportunity cost of the proposed reductions as they invest greater time and labour, and hence are keen about their tomato crop yield. This finding is similar to the Mulwa et al. (2017) study that shows positive relation of on-farm work with adoption of climate risk mitigation strategies. Similarly, Alabi et al. (2014) study also indicates that farm households' labour has a positive correlation with use of agrochemicals.

Model 2 presents the factors that explain farmer perceptions regarding the impact of one-third reduction in pesticide use on tomato fruit size (Table 4.4). Interestingly, farm size, farm ownership, disease outbreak, price reduction with one-third lower pesticide use, and farmer training to apply agrochemicals are still significant with the same coefficient signs. The interpretation of the results for the above-mentioned variables is the same across the two models (Model 1 and 2) except for some of the average marginal effects. For example, in Model 2, farm owners are 16 percent more likely to believe that tomato crop fruit size would remain the same with one-third reductions in pesticides. Likewise, farmers with training to apply agrochemicals are 15 percent more likely to perceive that one-third reduction in the use of pesticides are harmless to the tomato fruit size. Both of these results are in line with Kabir and Rainis (2015) study.

Nevertheless, farmer education and market distance also explain the impact of one-third reductions in pesticide use on tomato fruit size in Model 2. Farmer education is significant with a positive sign, implying that farmers with greater education are more likely to perceive that one-third reduction in the pesticide use are benign for the fruit size of tomato crop. Since there is already an overuse of the pesticides in tomato crop in study areas, educated farmers may consider one-third reduction as harmless. This indicates that farmer education can play a positive role in the uptake of sustainable agricultural practices and thereby cleaner food production. This is similar to the results of Tatlıdil et al. (2009) that show a positive relation between farm household education and sustainable agricultural practices. Furthermore, this finding also complements the result of agrochemical use training in these estimates.

Market distance is significant with a negative sign, which means that farm households which are further from the market are more likely to believe that one-third reduction in pesticide use will reduce the fruit size of the tomato crop. This is probably because farm households with a greater distance from the market usually get low farm gate prices due to the increased transportation cost of retailers; however, the tomato production cost is the same. Hence, these farmer households are unwilling to take the risk of reducing the pesticides. This is similar to the negative correlation of market distance in vegetable commercialization in Megerssa et al. (2020) study.

Table 4.5: Average marginal effects of the factors affecting farmer perceptions

Variables	**33% pesticide reductions**		**No pesticide use**	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Farmer age	-	-	0.003	0.003
	-	-	(1.69)	(1.80)
Farmer education	-	0.014	-	-
	-	(2.03)*	-	-
Farm size	-0.006	-0.004	-0.003	-
	(2.65)**	(2.18)*	(1.84)	-
Farm ownership	0.186	0.163	0.118	-
	(3.25)**	(2.51)*	(2.21)*	-
Disease outbreak	-0.062	-0.045	-0.067	-0.051
	(3.24)**	(2.01)*	(3.78)**	k(2.38)*
Price reduction with 33% lower pest.	-0.002	-0.004	-0.002	-0.002
	(3.11)**	(3.76)**	(2.26)*	(2.30)*
Agrochemical use training	0.132	0.152	-	-
	(2.39)*	(2.02)*	-	-
On-farm work	-0.025	-	-	0.014
	(2.79)**	-	-	(1.80)
Market distance	-	-0.003	-	-
	-	(2.73)**	-	-
Off-farm income	-	-	-	-
	-	-	-	-
Tomato crop area	-	-	0.009	-
	-	-	(2.36)*	-
Tomato yield	-	-	-	-
	-	-	-	-
Tomato farm gate price	-	-	-	-
	-	-	-	-
Observations	256	256	255	256

Model 3 and 4 present the factors that explain farmer perceptions of same tomato crop yield and fruit size with complete elimination of pesticides. Model 3 estimates show that farmer age, farm size, farm ownership, disease outbreak, tomato price reduction with one-third lower pesticide use, off-farm income, tomato crop area, and tomato yield per season affect farmer perceptions. Farmer age has a positive impact on farmer perceptions of same tomato crop yield if pesticides are eliminated, implying that older farmers are more likely to believe that tomato crop can survive without the use of pesticides.

Conceivably, this is because of the fact that old farmers have done farming before the advent of modern agricultural technologies. Kabir and Rainis (2012) and (2015) studies also observed that older farmers retain a positive perception towards pest management.
Results of farm size, farm ownership, disease outbreak, tomato price reduction with one third lower pesticide use, and farmer training to apply agrochemicals in Model 3 are similar to those which are in Model 1 and 2, except for some of the average marginal effects. For example, farm owners in Model 3 are 12 percent more likely to believe that tomato crop yield would remain the same with one-third reduction in pesticide use. Likewise, disease outbreak results show that each additional outbreak experienced by farmers in the past five years reduces their likelihood to perceive the same yield with lower pesticides by almost seven percent.

Off-farm income has a negative sign in Model 3, indicating that farmers with off-farm income are less likely to perceive that complete elimination of pesticide is benign for tomato crop yield. The most plausible reason for this is that off-farm sources of income in study areas are usually temporary and uncertain. This is in addition to the possibility that households with off-farm income are large which have greater expenses, and hence they perceive a risk from proposed changes. Zhang et al. (2018) reported a similar result which shows off-farm income has a negative impact on farmer readiness to reduce the use of pesticides. However, Ma et al. (2018) suggests that off-farm income has a positive impact on the purchase of fertilisers and pesticides.

The coefficient of tomato crop area is positive, implying that farmers who grow tomato crop on large area are more likely to perceive that complete elimination of pesticides would not affect the tomato crop yield. Conceivably, this is because farmers incur high pesticide costs as they have a large area of tomato crop. Furthermore, it is easy to detect the disease outbreak and prevent it from spreading when the crop area is large. The result of this variable is similar to the Kabir and Rainis (2015) study on pest management. On the other hand, the coefficient of tomato crop yield per season (in mounds) is negative, indicating that farmers who get greater tomato yield are less likely to believe that the complete elimination of pesticides would be harmless to their tomato crop yield. Most plausibly, these farmers seek to maximize their revenue from tomato crop and are more sensitive to the proposed reductions. Hence, they believe that proposed reductions would have an impact on the crop yield.

Model 4 investigates farmer perceptions with regards to the impact of pesticide elimination on fruit size of the tomato crop (Table 4.4). Again, farmer age, disease outbreak, tomato price reduction with one-third lower pesticide use have similar results to the previous models (Model 1, 2 and 3), and hence their interpretation is consistent. However, unlike Model 1, on-farm work has a positive coefficient, which means that farm households with more members working on farm are more likely to believe that complete elimination of pesticides would be undisruptive to the tomato crop fruit size. This is in contrast to Alabi et al. (2014) study also indicates that farm households' labour has a positive correlation with use of agrochemicals. This suggests that farmers might retain different perceptions about the impact of pesticide reductions on tomato yield than that on the fruit size.

Table 4.6: Factors affecting farmer perceptions of the same yield and fruit size

Variables	**33% fertiliser reductions**		**No fertiliser use**	
	Model 5	**Model 6**	**Model 7**	**Model 8**
Farmer age	-0.020*	-0.012	0.014*	0.020***
	(0.011)	(0.009)	(0.008)	(0.007)
Farmer education	-0.002	0.023	-0.025	-0.021
	(0.034)	(0.030)	(0.024)	(0.023)
On-farm income	1.08e-06*	9.97e-07*	-	-
	(5.67e-07)	(5.17e-07)	-	-
On-farm work	-0.161**	-0.088*	-	-
	(0.070)	(0.048)	-	-
Farm size	-0.082**	-0.025*	-	-
	(0.036)	(0.014)	-	-
Price reduction with 33% lower pest.	-0.732**	-0.520*	-	-0.420*
	(0.323)	(0.281)	-	(0.250)
Tomato crop area	0.085*	-	-	-
	(0.051)	-	-	-
Disease outbreak	-	-	-0.322***	-0.222**
	-	-	(0.097)	(0.091)
Tomato farm gate price	-	-	0.0002*	-
	-	-	(0.0001)	-
Agrochemical use training	-	-	-0.654*	-
	-	-	(0.350)	-
Tomato yield	-	-	-	0.0002*
	-	-	-	(0.0001)
Constant	0.475	-0.227	-1.070***	-1.089***
	(0.666)	(0.542)	(0.412)	(0.415)
LR chi-square	27.85	17.98	26.20	27.25
Pseudo-R2	0.19	0.10	0.12	0.12
Log-likelihood	-58.70	-77.267	-92.65	-98.82
Observations	256	256	256	256

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Coefficient of tomato farm gate price has a negative sign, implying that those farmers who receive higher farm gate price for their tomato crop are less likely to believe that complete elimination of pesticides would be harmless to the fruit size of their tomato crop. It is reasonable to believe that farmers who get a higher farm gate price for their tomato crop are more conscious about the colour and freshness of their produce as these determine the price. Hence, they are disinclined to believe that complete elimination of pesticides would be benign to the tomato fruit size. This is in accord with previous research e.g. Kimbi et al. (2020) which shows positive relation of produce price with fertiliser use.

Table 4.6 presents the results of the factors that affect farmer perceptions of the impact of fertiliser reductions on the tomato crop yield and fruit size. Model 5 and 6 are estimated for one-third reduction in fertiliser use and Model 7 and 8 represent no fertiliser use. Model 5 estimates disclose that farmer age, farm size, farm income, on-farm work, tomato price reduction with lower pesticide use, and tomato crop area determine farmer perceptions of tomato crop yield and fruit size with fertiliser reductions. Farmer age has a negative coefficient, which means older farmers are less likely to believe that tomato crop yield would remain the same with one-third reduction in fertiliser use and hence might be reluctant to adopt the proposed changes. While this contrasts with results of this variable in Model 3 and 4, it is plausible to assume that older farmers feel reluctant to adopt the changes, as also reported in Kimbi et al. (2020) for improved seed varieties.

Farm income in Model 5 is positive, indicating that farmers who have greater incomes from farming are more likely to perceive that one-third reductions in the use of fertilisers would be benign to the tomato crop yield. It is reasonable to say that farm households with greater income from farming are more resilient, and hence are willing to take the risk of implementing one third reductions in fertiliser use. Vidogbena et al. (2016) also report that farm income positively influences the adoption of agricultural technologies. Furthermore, research shows that higher income enables farmers to take greater risks and absorb shocks should the new technology fail (Dercon and Christiaensen, 2011).

As observed before, on-farm work has a negative coefficient, implying that farm households with a greater number of on-farm workers are less likely to believe that one-third reduction in fertilisers would be harmless. This is believably due to farm households' greater opportunity cost of proposed changes as they have greater time and labour investment, and hence an expectation to get the higher crop yield. In this regard, De Jalón et al. (2015) demonstrated that households with more family members working on-farm are more likely to be critical of the sustainable agricultural practices.

Large farmers are less likely to believe that one-third reduction in fertilisers would be harmless to the tomato crop yield, which is possibly due to large farmers' greater investment and deployment of resources, and thus a higher perceived risk of disease outbreak. Likewise, perceived price reduction with lower pesticides is negative, showing that farmers who have perceived a greater decrease in tomato price with lower pesticides are nine percent less likely to think that one-third reduction in fertilisers would be harmless to the tomato crop. The above two findings are in-line with Pilarova et al. (2018) study which shows that farmer risk perceptions drive their adoption of sustainable agricultural practices. Tomato crop area has a positive coefficient, which suggests that farmers who grow tomatoes on large area are more likely to believe that one-third reduction in fertilisers will be benign to the tomato crop yield. This is in line with the results of Kabir and Rainis (2015) study.

Model 6 includes the factors that affect farmer perceptions of the same fruit size with one-third reduction in fertilisers. In this model, the parameter estimates as well as average marginal effects of the significant variables such as farm income, on-farm work, farm size and perceived price reduction with one-third lower pesticides are similar to those in Model 5. Since, therefore, the descriptions of the results of the mentioned variables are also same for both models, it is unnecessary to repeat those.

Model 7 and 8 include the factors that affect farmer perceptions of same tomato crop yield and fruit size with complete elimination of all fertilisers. Results of Model 7 reveal that farmer age, disease outbreak, tomato farm gate price and agrochemical use training are significant. Farmer age has a positive coefficient, which means that older farmers are more likely to maintain that tomato crop yield would be unaffected if fertilisers are completely abolished. Conceivably, this is because of older farmers' experience of farming, as indicated in previous research (Kabir and Rainis, 2012), before the emergence of synthetic fertilisers. However, this is in contrast to the models estimated for one third reductions in fertilisers in addition to previous research that suggests that older farmers are more risk averse (Fisher et al. 2018; Petway et al. 2019). It is worth noting that the change in the sign and significance of the farmer age variable has also been observed in models estimated for pesticide use reductions (Model 3 and 4).

Disease outbreak in Model 7 is significant with a negative sign, implying that farmers who have experienced a greater number of major disease outbreaks in the past five years are less likely to believe that complete removal of fertilisers would be harmless. Each additional disease outbreak experienced by farmers in the past five years reduces their likelihood to perceive the same yield without fertilisers by almost 7 percent. This is in line with Suit-B et al. (2020) study that indicates that negative past experiences with disease outbreaks made farmers more careful to avoid reliving negative past experiences.However, tomato farm gate price has a positive sign, suggesting that farmers who receive relatively higher farm gate price for their tomato crop are more likely to perceive that fertiliser removal would be benign to the tomato crop yield. This contrasts with the result of tomato farm gate price in Model 4, where it has a negative sign.

Surprisingly, unlike model estimates for pesticide reductions, coefficient of farmers' agrochemical use training has a negative sign, which shows that farmers who have received the training to apply agrochemicals in their tomato crop are 13 percent less likely to perceive that complete elimination of fertilisers would be undisruptive to the tomato crop yield. This is an interesting result which shows that while farmers have learned the preventive use of pesticides, they perceive fertiliser use more crucial for tomato crop than their counterparts who did not receive the training. Furthermore, this also suggests that perhaps the training that farmers have received from agricultural extension had more emphasis on the precise use of pesticides.

Results of Model 8 unveil that farmer age is significant with a positive sign, implying that older farmers are more likely to believe that tomato fruit size would be unaffected with complete elimination of fertilisers. The result of this variable is similar to that in the Model 3 and 4. Most probably, this is because older farmers have done tomato farming before the crop intensification period. Moreover, older farmers' experience of using manure could also be a reason as they are aware of a substitute to the synthetic fertilisers. The results of price reductions with lower use of pesticides and disease outbreak in Model 8 are similar to those in the previous estimates for pesticide as well as fertiliser reductions; hence, the same interpretations hold for these variables.

Table 4.7: Average marginal effects of the factors affecting farmer perceptions

Variables	**33% fertiliser reductions**		**No fertiliser use**	
	Model 5	**Model 6**	**Model 7**	**Model 8**
Farmer age	-0.002	-0.002	0.003	0.004
	(1.77)	(1.31)	(1.91)	(2.75)**
Farmer education	-	0.004	-0.005	-0.005
	-	(0.76)	(1.03)	(0.92)
On-farm income	-	-	-	-
	-	-	-	-
On-farm work	-0.020	-0.014	-	-
	(2.30)*	(1.83)	-	-
Farm size	-0.010	-0.004	-	-
	(2.25)*	(1.80)	-	-
Price reduction with 33% lower pest.	-0.090	-0.085	-	-0.090
	(2.28)*	(1.86)	-	(1.70)
Tomato crop area	0.010	-	-	-
	(1.67)	-	-	-
Disease outbreak	-	-	-0.064	-0.048
	-	-	(3.43)**	(2.47)*
Tomato farm gate price	-	-	-	-
	-	-	-	-
Agrochemical use training	-	-	-0.130	-
	-	-	(1.89)	-
Tomato yield	-	-	-	-
	-	-	-	-

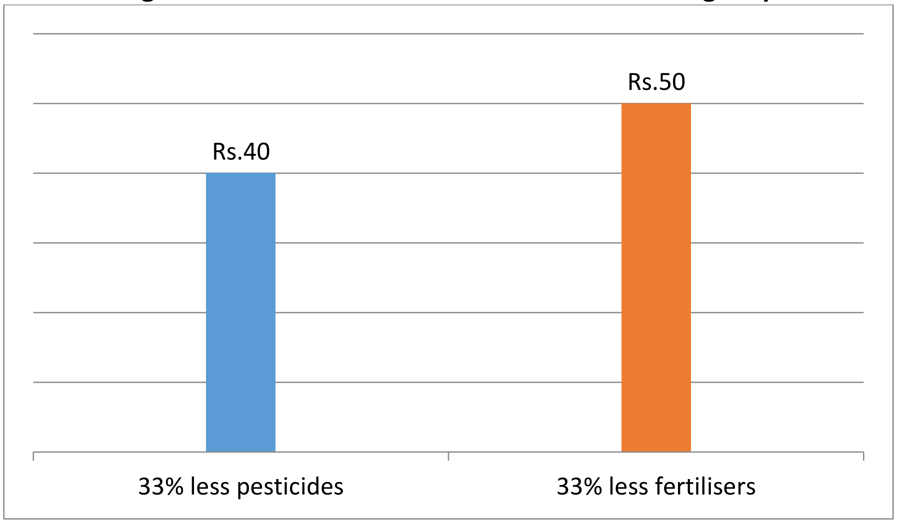
Tomato yield per season has a positive coefficient, which shows that farmers who get greater tomato yield in a season are more likely to perceive that complete elimination of fertilisers would be harmless for fruit size of the tomato crop. This is possible with new tomato crop varieties which are more efficient, i.e. the cultivation requires less inputs including fertilisers. Furthermore, as farmers also use manure in the tomato crop, they are aware of the substitute to synthetic fertilisers. However, this is in contrast to the results for pesticide use reduction, which is expected as complete elimination of pesticides can cause crop failure.

Econometric analysis performed to investigate farmer perceptions of the impact of proposed pesticide and fertiliser reduction on tomato crop yield and fruit size uncovers the drivers of farmer perceptions, which include socioeconomic and farm related factors that explain the variations in farmer perceptions. *This section addresses the second research question of this thesis (outlined in Chapter 1) which aims to explore the factors that explain farmer perceptions of different agricultural practices.*

4.4.6 Farmer perceptions of impact of proposed changes on tomato farm gate price

The present research also investigates farmers' perceived impact of proposed changes on tomato farm gate price (Figure 4.12). The following question(s) were used to explore the farmers' perceptions. *"What tomato price reduction (Rs/mound) do you expect if pesticides (fertilisers) use is reduced by 33% ______"* These are Q.no: 25 and 34 in the farmer survey questionnaire attached in appendix-IV. Data reveal that farmers expect an average decrease of 40 rupees per mound in tomato farm gate price as a result of one-third reduction in pesticides. Similarly, farmers believe that one-third reduction in the use of fertilisers would decrease farm gate price by at least 50 rupees for each mound of tomatoes.

Figure 4.12: Perceived decrease in tomato farm gate price

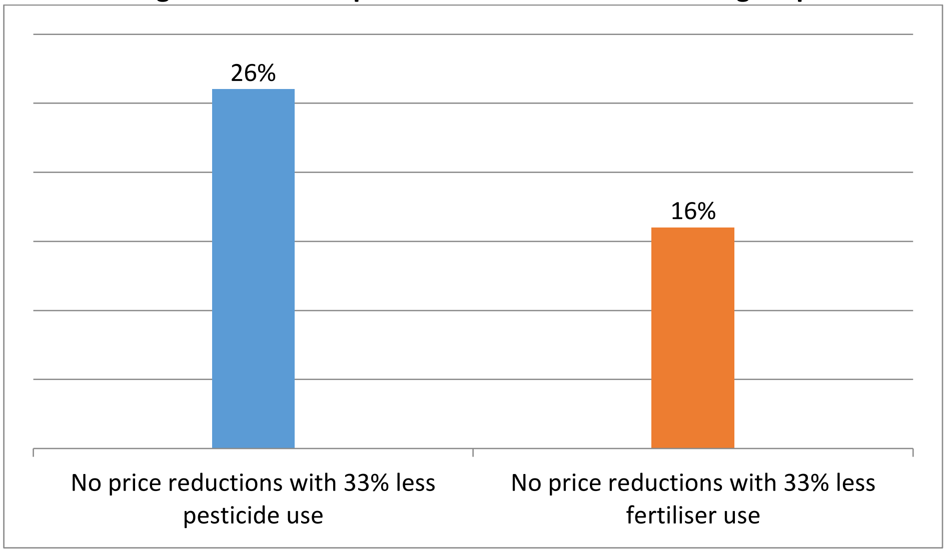


This shows that on average farmers perceive a negative impact of proposed pesticide and fertiliser reductions on tomato farm gate price. Nevertheless, considering the high cost of agrochemicals and the low farm gate price of tomato, some farmers might be willing to reduce the agrochemical use and adopt the sustainable agricultural practices as there is a premium on cleaner tomatoes. This could become more promising if farmers are incentivised to decrease the application of pesticides and fertilisers to adopt the sustainable agricultural practices for cleaner tomato production, which is the central idea of this thesis as farmers would get a price premium on their cleaner produce.

Again, while majority farmers (26 percent) think that the proposed reductions in pesticides and fertilisers would reduce the farm gate price of tomatoes, a fraction of them (16 percent) believe that tomato farm gate price would be unaffected (Figure 4.13). This means that there is heterogeneity in farmer perceptions (as observed before in case of tomato crop yield and fruit size) of the impact of the proposed changes on tomato farm gate price. This variation could be due to various factors which determine farmer perceptions.

This section adds to the answer of the first research question of this thesis (presented in Chapter 1) that investigates farmer perceptions of the impact of proposed changes on tomato crop.

Figure 4.13: Perception of the same tomato farm gate price



This, therefore, requires investigation of the factors including farmers' socio-demographic attributes to explain the heterogeneity in farmer perceptions regarding the impact of proposed changes on tomato farm gate price. This variation however is crucial as it could have favourable implications for the implementation of sustainable agricultural practices. For this purpose, the following section presents the results of a probit regression which investigates the factors that affect farmer perceptions of tomato farm gate price with one-third reductions in the use of pesticides and fertilisers.

4.4.7 Factors affecting farmer perception of the same tomato farm gate price

Model 9 estimates explain the factors of farmer perception for one-third reduction in pesticides and Model 10 estimates show drivers of farmer perception for one-third reduction in fertilisers (Table 4.8). The dependent variables in both equations are dummies, where '1' represents farmer perceptions of the same farm gate despite reduction in pesticides and fertilisers and '0' otherwise. Likelihood ratio (LR) test indicates that the overall fit of the models is good.

Results of Model 9 show that farmer education, household size, farming experience, on-farm work, and tomato yield and disease outbreak are some of the variables that explain farmer perceptions of same farm gate price with one-third reduction in pesticides. The coefficient of farmer education has a negative sign, showing that farmers who have greater education are less likely to believe that one-third reduction in pesticides would be harmless to the tomato farm gate price. This is probably because of educated farmers' greater awareness of price sensitivity to color and freshness of produce which is affected by pesticide use. Furthermore, education also affects farmer risk perceptions as indicated in previous research (Ullah et al. 2015; Rizwan et al. 2020).

Household size also has a negative coefficient, indicating that farmers who have large households are less likely to believe that tomato farm gate prices would remain unaffected with one-third reduction in pesticides. It is probably because farmers with large household size feel more risk from the proposed changes due to their greater dependence on tomato crop, which is expected as tomato is a cash crop and there are limited off-farm income opportunities in rural areas. Farmers with greater farming experience are also less likely to consider the impact of one-third reduction in pesticides on price as ineffectual. It is plausible to say that older farmers have more experience of price negotiations with tomato dealers who value the tomato size, freshness and colour which improve with the application of agrochemicals. Nonetheless, research shows that greater household size and farming experience contribute to the farmers' risk aversion (Ullah et al. 2015; Shah et al. 2017).

Table 4.8: Factors affecting farmer perceptions of the same tomato farm gate price

Variables	**33% pesticide reductions**		**33% fertiliser reductions**	
	Model 9	**Average marginal effects**	**Model 10**	**Average marginal effects**
Farmer age	-	-	0.022*	0.005
	-	-	(0.013)	(1.72)
Farmer education	-0.033	-0.010	-0.002	
	(0.022)	(1.50)	(0.026)	-
Household size	-0.057*	-0.017	-	-
	(0.031)	(1.91)	-	-
Farming experience	-0.015**	-0.005	-0.039***	-0.008
	(0.007)	(2.25)*	(0.013)	(2.99)**
On-farm work	0.080**	0.024	-	-
	(0.034)	(2.45)*	-	-
Tomato yield	-0.0002*	-	-	-
	(0.0001)	-	-	-
Disease outbreak	0.211***	0.063	0.463***	0.096
	(0.074)	(2.94)**	(0.099)	(5.06)**
Constant	1.052***	-	0.301	-
	(0.341)	-	(0.414)	-
LR chi-square	23.15	-	35.02	-
Pseudo-R2	0.08	-	0.16	-
Log-likelihood	-135.28	-	-95.11	-
Observations	256	-	256	-

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

On-farm work, on the other hand, is significant with a positive sign, implying that farm households with a greater number of household members working on farm are more likely to believe that the tomato farm gate price will be unaffected with one-third reductions in pesticides. This is an intriguing result, which suggests that more time and labour investment on tomato crop might compensate for the impact of some of the reductions in the use of agrochemicals. This result itself has powerful policy implications for tomato crop farmers as well as agricultural extension. This is however in contrast to the studies cited above by Mulwa et al. (2017) and Alabi et al. (2014).

Tomato yield per season has a negative coefficient, which means that farmers who get more tomato yield per season are less likely to consider that one-third reduction in pesticides would be harmless to tomato farm gate price. This is possibly because farmers who get more tomato yield rely on concentrated use of agrochemicals, and hence are reluctant to reduce those. Surprisingly, disease outbreak variable is significant and positive, indicating that farmers who have experienced a greater number of major disease outbreaks in the past five years are more likely to believe that one-third reduction in pesticides would be benign to the tomato farm gate price. In fact, each additional outbreak experienced by farmers increases their likelihood to perceive the same tomato farm gate price by almost 6 percent. Possibly this is due to farmers' greater knowledge and experience of disease management which has improved their confidence in overall tomato crop management.

Model 10 presents the estimates of farmer perceptions of farm gate price as a result of one-third reduction in fertilisers. Farming experience and disease outbreak are significant with the same sign as those with pesticide reductions. However, Model 10 results show that each additional outbreak increases farmer likelihood to perceive the same tomato farm gate price by almost 10 percent. Farmer age is positive and significant, which indicates that older farmers are more likely to perceive one-third reductions in fertilisers as undisruptive for tomato farm gate price. This means that older farmers do not see significant impact of one-third reduction in fertilisers on tomato farm gate price, which is similar to the previous estimates where farmer age is positive for the advanced level of reductions.

Empirical findings presented in this section answer the second research question of the present research (outlined in Chapter 1) which aims to explore the factors that explain farmer perceptions of different agricultural practices.

The next section presents the results of consumer perceptions regarding different farming practices.

4.4.8 Consumer sample characteristics

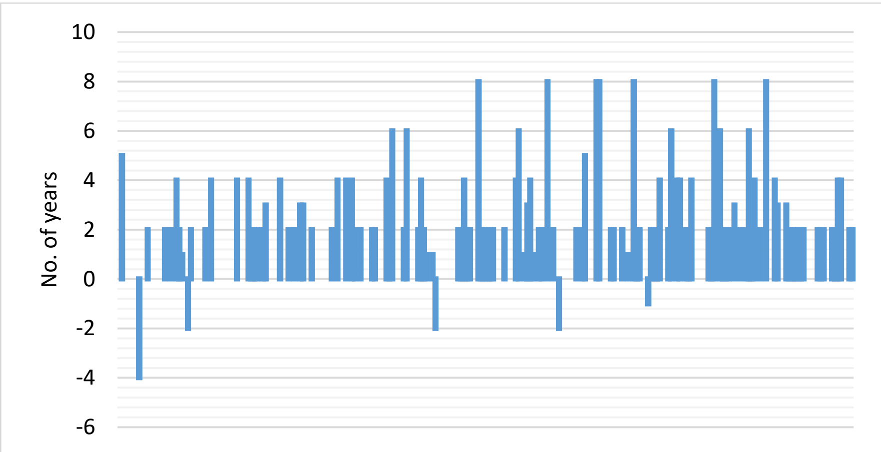
The consumer survey was administered with the vegetable consumers in Islamabad city. The average age of the respondents in the consumer survey is 36 years. The average years of formal education are 15 (Table 4.9), which means that this sample is composed of young people who are also educated. This is expected as the study site is an urban setting with relatively higher socioeconomic standard. Average of the household head education is around 15 years. The data were also collected on the ‘maximum years of education’ in a household due to its possible influence on households’ decision-making. The average of the maximum years of education in consumer households is 17 years. Furthermore, the maximum years of education of the consumer is significantly greater than the average education of the household head (Figure 4.14). Data shows that the average of the household monthly income is 152,496 Pakistani rupees (USD 958.336 at 12/07/2019), while the minimum reported monthly income is 20,000 Pakistani rupees (USD 125.687 at 12/07/2019).

Table 4.9: Consumers’ socio-demographic characteristics

Characteristics	Mean	St. Dev.	Min.	Max.
Age (years)	36.601	10.742	18	72
Education (years of schooling)	15. 754	2.311	8	22
Max. education (years of schooling)	17.082	1.982	10	22
Household income (PKRs)	152,496	123,821	20,000	1,500,000
Gender	0.313	0.462	0	1
Household size	6.339	3.094	2	35
Tomato consumption (kgs)	2.871	1.602	0	10
Children	1.556	1.527	0	6
Awareness[7]	0.495	0.5	0	1

This indicates that the sample is drawn from diverse income groups, which can be seen in Figure 4.15. However, the monthly average household income in this sample is higher than that of urban Punjab (45,283 PKRs) (which includes Islamabad) in the Pakistan Household Integrated Economic Survey 2015-16. This is because the study sample includes relatively affluent respondents, as indicated above.

Figure 4.14: Difference of average and maximum education

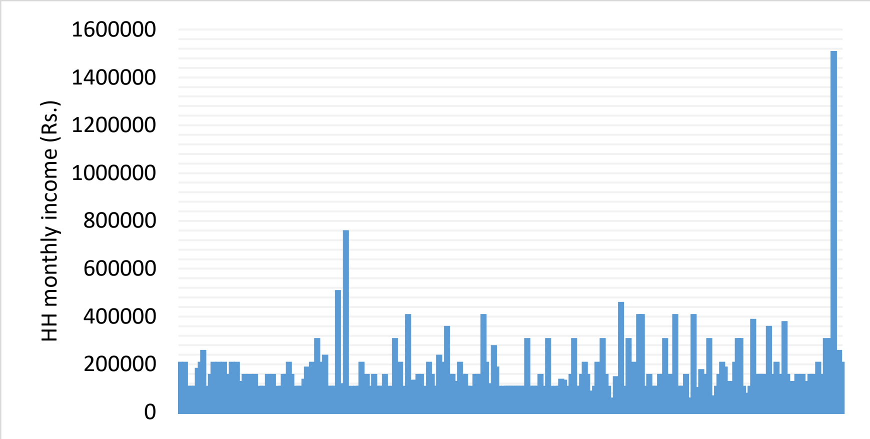


Approximately 69% respondents in this survey are women, as it is an urban setting and women prefer to do the shopping while male members of the household work outside. Furthermore, in Pakistani culture, women are often in charge of household chores, especially cooking and shopping groceries. The average household size of the sample is six, which is in line with the Population Census 2017 data

[7] Consumer awareness of the amounts of agrochemicals used in tomato crop production.

of Urban Islamabad. The weekly average tomato consumption of households in the sample is approximately three kilograms.

Figure 4.15: Household average monthly income



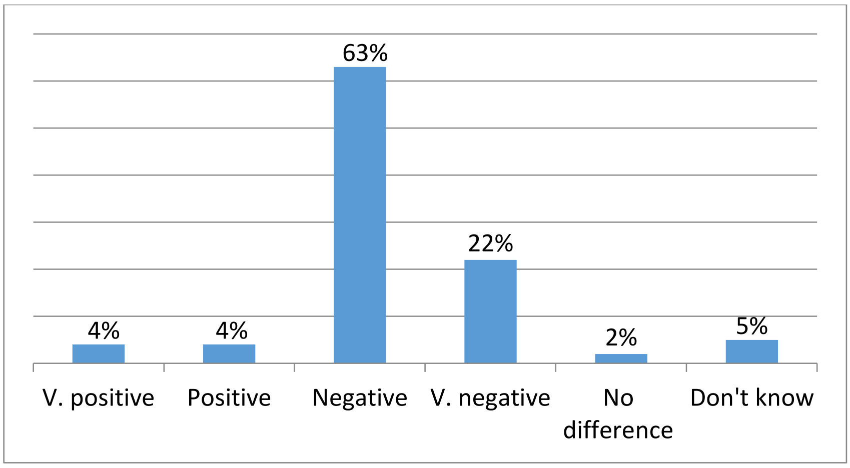
Next section presents a discussion on the consumer perceptions of the existing agricultural practices and the proposed changes required for cleaner tomato production.

4.4.9 Consumer perceptions of health and environmental impact of agrochemicals

This section includes consumers' perceived impact of agrochemical use on their health and the environment. The question statements which were used to reveal consumer perceptions have the following format: *"How do the pesticides (fertilisers) applied to the vegetables you eat affect your health (the environment)?"* with the options being "*1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know*". These are Q.no: 53 to 56 in the consumer survey questionnaire attached in appendix-IV.

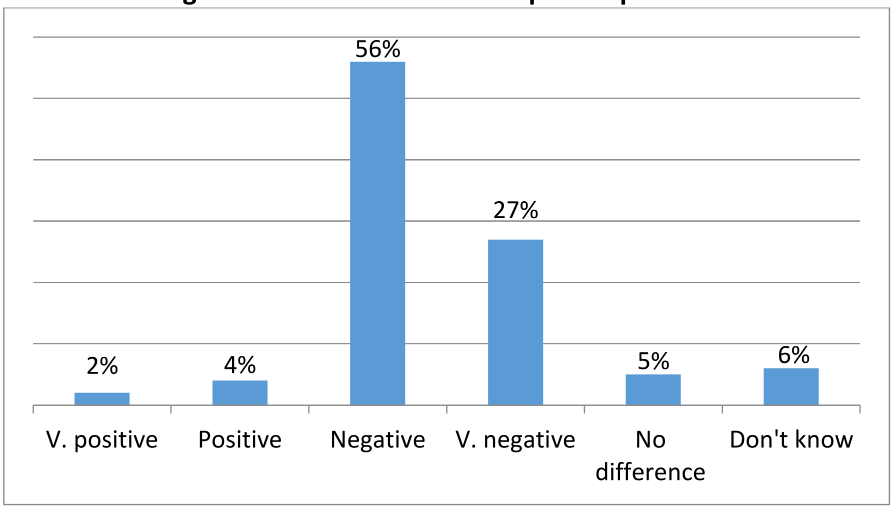
While a small fraction of tomato consumers in Islamabad seems to be unaware of the pesticides' health impacts, majority respondents (roughly 85 percent) think that the pesticides used in vegetable cultivation are harmful for their health (Figure 4.16). This response is expected from a relatively educated sample. An important factor that contributes towards the increased consumer awareness regarding pesticides use in food production is the prevalent food adulteration in Pakistan. It is very common to come across the news about the poor health and safety standards and a lack of compliance to the regulations in food production and sale.

Figure 4.16: Health impact of pesticide use



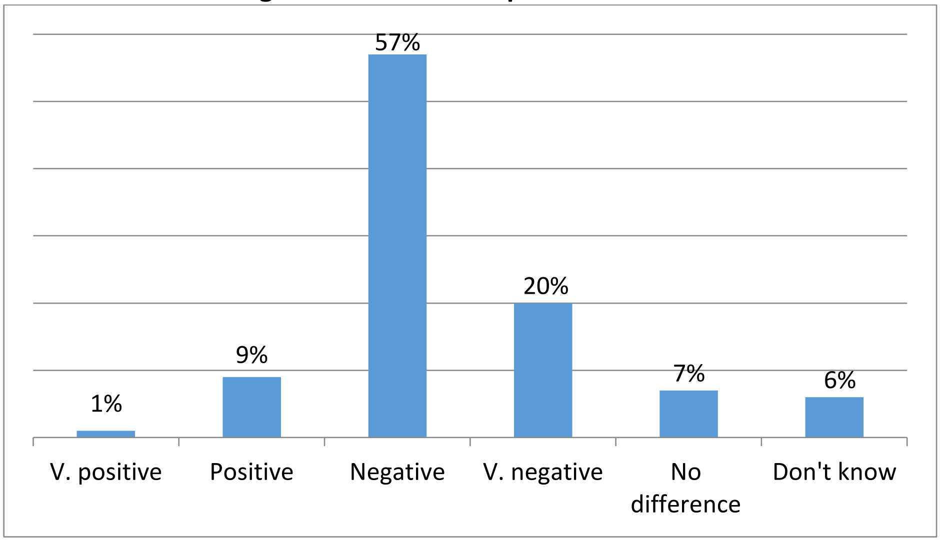
Similarly, survey responses reveal that approximately 83 percent respondents think that the pesticides that are used to grow the vegetables have a negative impact on the natural environment (Figure 4.17). Again, a small fraction of survey respondents lack awareness, which is expected as some of the respondents have low education (see Table 4.9), as indicated in previous research (My et al., 2017; Khouryieh et al., 2019). Furthermore, considering the food inflation and a relatively high cost of living in Islamabad, consumers from the lower socioeconomic strata cannot afford to purchase expensive food, hence they might be more concerned about food prices than the quality of the food they purchase.

Figure 4.17: Environmental impact of pesticide use



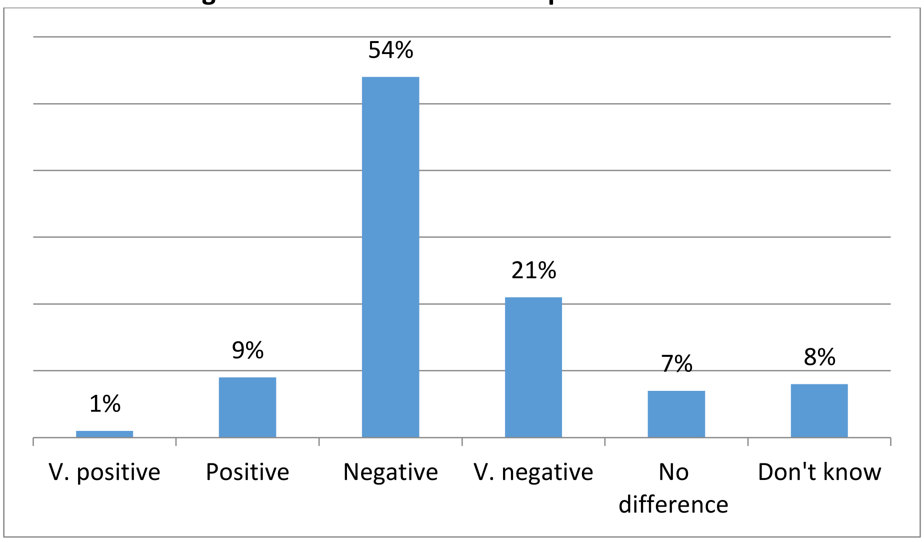
Data on consumer perceptions with regards to the health impacts of fertiliser application show that roughly 77 percent consumers believe that fertiliser use in vegetable production has a negative impact on their health (Figure 4.18). While fertiliser use causes water contamination and heavy metals are harmful for human health, fertilisers might not be as dangerous as pesticides for human health. This finding suggests that consumers might not possess the technical information regarding the impacts of fertiliser use.

Figure 4.18: Health impact of fertiliser use



Since Pakistani farmers' use of fertilisers is generally higher than the recommended amounts, consumers are possibly alarmed about the overdose. Furthermore, there is usually poor monitoring of relevant authorities and the thin compliance by the producers. Nevertheless, some respondents seem to be unaware of the impacts of fertiliser use on human health, as shown in previous research e.g. Badrie et al. (2006) and Khouryieh et al. (2019).

Figure 4.19: Environmental impact of fertiliser use



Data on consumer perceptions regarding the impact of fertilisers on the environment disclose that 65 percent consumers think that fertiliser use has a negative impact on the environment (Figure 4.19). As majority consumers in study areas are educated, they have a general understanding of how excessive use of fertilisers is polluting soil, water and air. Furthermore, overall environmental depletion and a lack of stringent monitoring by the relevant departments including Environmental Protection Agencies (EPAs) also shape consumer opinions. Yet again, there are consumers who lack the awareness of the impacts of fertilisers on the environment and it is expected. These findings show that majority consumers understand that pesticide and fertiliser use have negative consequences for both human health and the environment.

This section of the results answers the first research question (outlined in Chapter 1) which investigates consumer perceptions of the existing agricultural practices used in tomato crop.

Next section discusses consumer awareness of the agrochemical use in tomato crop.

4.4.10 Consumer awareness of the agrochemical use

Consumers' awareness of the food production practices could affect their choices with regards to food purchase and consumption. In this context, the present research has investigated consumer awareness of the use of agrochemicals in the tomatoes they consume. The question that was asked in the survey to reveal consumer awareness of the amounts of agrochemicals being used is as follows: *"Are you aware that considerable amounts of fertilisers and pesticides are used in growing tomatoes?"* with "*1= yes, 0= no*" options. This is Q.no: 52 in the consumer survey questionnaire attached in appendix-IV.

Data show that almost half of the survey participants (51 percent) are aware of the amounts of agrochemicals that farmers use to grow the tomatoes. Previous research has also reported gaps in food safety awareness and knowledge (Badrie et al., 2006; My et al., 2017; Khouryieh et al., 2019). However, survey participants with or without awareness of the amounts of agrochemicals that farmers apply in their tomato crop are from the same area. Hence, this warrants further investigation of variation in awareness of a seemingly homogenous sample. Most likely this is due to the differences in consumer socio-demographic and personal characteristics. In this regard, a probit regression is deployed to ascertain the factors that explain the consumer awareness of the amounts of agrochemicals which are being used in tomato crop in Khushab. The dependent variable is a dummy, where '1' represents consumer awareness of the amounts of the agrochemicals being used in tomato cultivation, and '0' otherwise. Likelihood ratio (LR) test indicates that the model exhibits significant fit and improvement over the baseline.

Probit estimates of the factors affecting consumer awareness are presented in Table 4.10 (Model 11). The significant factors include consumer age, gender, education, and average tomato consumption per week, consumer understanding of the organic vegetable, consumer health perceptions and their reading of ingredients/nutritional facts on food labels. The coefficient of consumer age is positive, implying that older consumers are more likely to be aware of the amounts of agrochemicals being used in the production of tomato crop. Older people in study area are often the head of the household, hence they may feel more responsible about food quality that their family members consume, as indicated by Liu and Niyongira (2017) and Redmond and Griffith (2004).

Gender variable is significant with a positive sign, indicating that male consumers are more likely to be aware of the amounts of agrochemicals being applied in tomato crop. The chances of male consumers being aware of the amounts of agrochemicals farmers use in tomato crop are 14 percent higher than female consumers. As stated earlier, this is because women in the Pakistani culture are in charge of household chores and usually stay inside their homes most of the time. Hence, it is less likely that the women in study area would have visited the tomato farms in Khushab or would be aware of the farming practices, including the use of agrochemicals. This finding is similar to the Zhen et al. (2019) study which indicated that male respondents tend to perceive higher food safety risk.

Table 4.10: Factors affecting consumer awareness of agrochemical amounts

Variables	Model 11	Average marginal effects
Age	0.017**	0.006
	(0.008)	(2.11)*
Gender	0.408**	0.140
	(0.191)	(2.19)*
Education	0.069*	0.024
	(0.040)	(1.74)
Tomato consumption	-0.138***	-0.047
	(0.052)	(2.77)**
Organic understanding	0.579***	0.199
	(0.184)	(3.34)**
Positive health perceptions	0.555*	0.191
	(0.297)	(1.91)
Read ingredients/nutrition facts	0.595**	0.204
	(0.283)	(2.15)*
Constant	-2.846***	-
	(0.797)	-
LR chi-square	45.74	-
Pseudo-R2	0.13	-
Log-likelihood	-154.56	-
Observations	256	-

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As expected, education has a positive influence on consumer awareness, showing that consumers with a greater number of years of schooling are more likely to be aware of the amounts of agrochemicals farmers apply in their tomato crop. Liu and Niyongira (2017) study also confirms this finding. Interestingly, tomato consumption per week is significant with a negative sign, which means that consumers with greater tomato consumption are less likely to be aware of the amounts of agrochemicals farmers use in the production of the tomatoes. Each additional kilogram of tomato consumption of a household reduces its likelihood of being aware of the amounts of agrochemicals by almost five percent. This clearly shows that these are large households with greater food expenditures who are possibly more concerned about food expense than the quality of food, including food production processes such as the use of agrochemicals.

The understanding of organic vegetables is significant with a positive coefficient, which means that the survey respondents who have an understanding of the organic vegetable are more likely to be aware of the amounts of agrochemicals that farmers use in the tomato crop. Expectedly, consumers who understand the meaning of organic vegetables are almost 20 percent more likely to be aware of the amounts of agrochemicals. The coefficient of consumer positive perceptions of their health also explains consumers' awareness regarding the amounts of agrochemicals farmers apply in their tomato crop. These consumers are almost 19 percent more likely to be aware of the agrochemicals used in the tomato crop. Conceivably, this is because these consumers are health conscious and they consciously seek the information about the production practices of the food they consume.

Similarly, consumers who read ingredients/nutritional facts while shopping the food are also more likely to be aware of the amounts of agrochemicals being applied in the tomato crop. Moreover, these consumers have nearly 20 percent higher probability of being aware than those who do not care to read ingredients/nutritional facts on food while shopping. Again, this is an expected result as consumers who keenly read the ingredients are those who care about the quality of the food they consume more than others.

Empirical results presented in this section address the second research question of the present research (stated in Chapter 1) which examines the factors that explain consumer perceptions of different agricultural practices being used in tomato cultivation in Khushab.

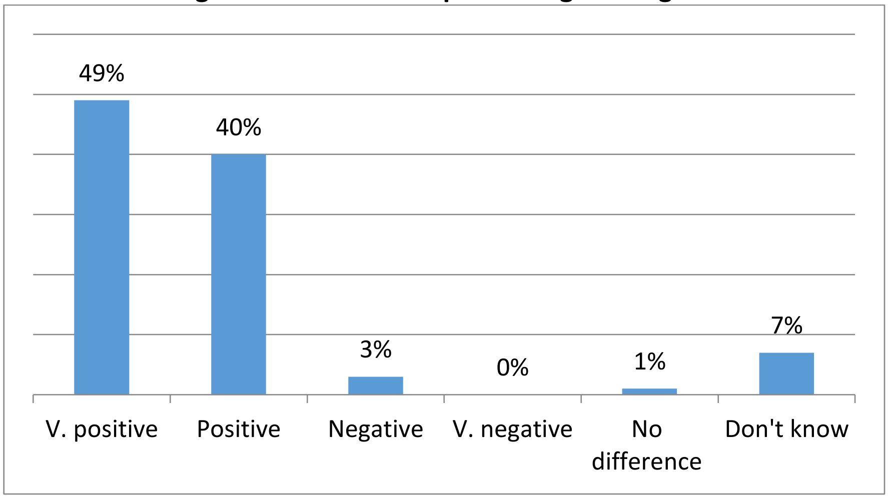
The next section discusses the consumer perceptions and understanding of organic vegetables.

4.4.11 Consumer perceptions of organic vegetables' health and environmental impact

This section presents the consumer perceptions of the impact of organic vegetables on their health and the environment. The question statements that were used to reveal consumer perceptions of the organic vegetables are as follows: "*How would consuming organic vegetables impact your health/the environment?*" with options being "*1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know*". These are Q.no: 58 and 59 in the consumer survey questionnaire attached in appendix-IV.

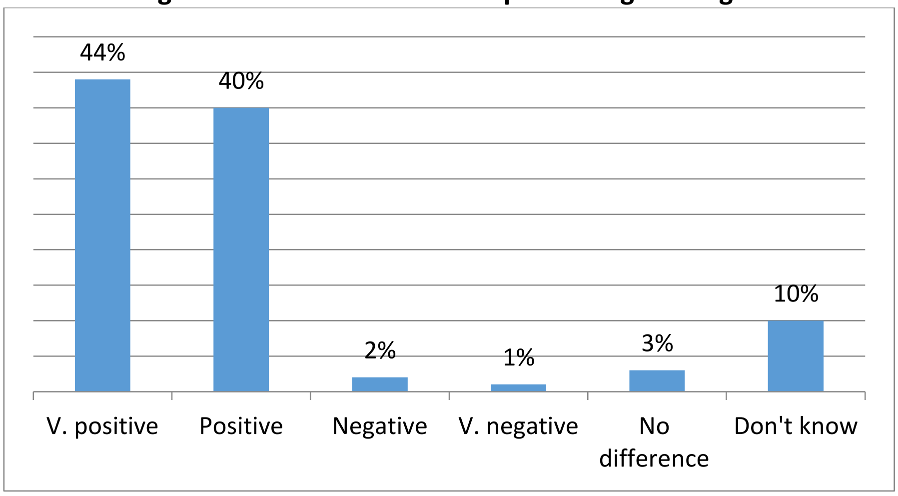
Similar to the results reported by Roitner-Schobesberger et al. (2008), roughly 89 percent consumers believe that consuming organic vegetables would have a positive impact on their health (Figure 4.20). While seven percent respondents have reported that they are unaware of the impact of organic vegetable consumption on their health, three percent think that it will have a negative impact on their health which obviously shows their lack of awareness. As pointed out by Wang et al. (2020), these results are expected from a study site where organic vegetables are not available in regular shops, and about 39 percent of respondents do not understand organic vegetables.

Figure 4.20: Health impact of organic vegetables



Data shows that approximately 84 percent consumers think that consuming organic vegetables would have a positive impact on the environment (Figure 4.21), which is also in consonance with Roitner-Schobesberger et al. (2008) study. However, the remaining 16 percent seem to be unaware of the impacts of organic vegetable consumption which is possibly due to their lack of education, and hence an understanding of the organic vegetable. This finding is similar to the results of Badrie et al. (2006). As stated above, the lack of availability of organic food in regular shops is also a reason for consumer unawareness of organic food.

Figure 4.21: Environmental impact of organic vegetable



The results presented in this section answer the first research question of the present research (outlined in Chapter 1) which investigates consumer perceptions of the existing agricultural practices used in tomato crop.

4.4.12 Consumer understanding of organic vegetables

Organic vegetables are not very common in Pakistan, i.e. it has a niche market where only few high-end producers are involved in the production of organic vegetables at a commercial scale and sell their produce to some of the selected stores and hotels. Hence, organic vegetables are not available in the regular vegetable markets and weekly bazaars to ordinary consumers. This is mainly because thus far the organic food industry has not developed enough in Pakistan; however, a lack of consumer awareness about the difference between organic and ordinary food, and a lack of affordability and/or willingness to pay a premium on cleaner produce are also the reasons. Thus, it is expected that some of the ordinary consumers may not know how an organic vegetable is exactly different from its regular counterpart sold in the shops. Furthermore, since this research proposes to use sustainable agricultural practices to produce health- and environment-friendly cleaner food, it is important to assess consumer awareness and understanding of cleaner food options as they will have to pay a price premium on relatively cleaner produce as a result of adoption of the proposed changes in the existing agricultural practices.

To assess the consumer understanding of the organic vegetable, survey respondents were asked to explain the organic vegetable in their own words. The question asked to assess the consumer understanding of organic vegetables is as follows *"Could you please explain the meaning of an 'organic vegetable'?"* with options of *"1= if they could explain, and 0= otherwise"*. This is Q.no: 57 in the consumer survey questionnaire attached in appendix-IV. Data shows that only 61 percent of consumers in the study area could explain the organic vegetable. This is in line with previous research (e.g. Roitner-Schobesberger et al. 2008, My et al., 2017 and Khouryieh et al., 2019) which indicates the gaps in consumer food safety knowledge; however, Zhang et al., (2018) reported that more than 90% consumers are familiar with organic vegetables. Here, the obvious question is why some consumers know and others do not. Hence, it is crucial to further investigate as to how consumers who understand organic vegetables are different from those who do not understand.

For this purpose, a regression analysis of the factors that determine consumer understanding of the organic vegetables is carried out using probit regression technique (Table 4.11). Likelihood ratio (LR) test indicates that the model exhibits significant fit and improvement over the baseline. Results of Model 12 show that the coefficient of consumer age is negative, implying that older consumers are less likely to be able to explain the organic vegetables, which is an expected result as the older consumers usually have less education and awareness. Furthermore, production of organic food at commercial scale is relatively a new phenomenon in Pakistan.

Education has a positive and significant coefficient, indicating that the consumers with a relatively greater number of years of schooling are more likely to understand organic vegetables, as expected.

Each additional year of education increases the likelihood of understanding organic vegetables by almost 5 percent. Liu and Niyongira (2017) also reported similar results in their study on consumer awareness regarding food safety. Consumers who are aware of the amounts of agrochemicals farmers apply to their tomato crop are more likely to understand the organic vegetables. Furthermore, the probability of understanding organic vegetables for consumers who are aware of the amounts of agrochemicals is almost 19 percent higher. This is due to their greater education and the awareness of the food production processes, as indicated by Zhang et al. (2018).

Table 4.11: Factors affecting consumer understanding of organic vegetable

Variables	Model 12	Average marginal effects
Age	-0.016*	-0.005
	(0.009)	(1.90)
Gender	-0.267	-0.083
	(0.196)	(1.37)
Education	0.168***	0.053
	(0.041)	(4.45)**
Agrochemical awareness	0.595***	0.186
	(0.181)	(3.50)**
Read ingredients/nutrition facts	0.584**	0.183
	(0.273)	(2.20)*
Food adulteration news	0.006**	0.002
	(0.002)	(2.50)*
Willingness to pay	-0.018*	-0.006
	(0.010)	(1.79)
No. of children	-0.097*	-0.030
	(0.051)	(1.94)
Constant	-2.233***	-
	(0.755)	-
LR chi-square	58.92	-
Pseudo-R2	0.17	-
Log-likelihood	-141.36	-
Observations	256	-

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Interestingly, as noted before, consumers who read ingredients and nutritional facts of the food are more likely to be able to explain the organic vegetables and their odds to explain the organic vegetables are 18 percent higher than others. This shows that it is not only the consumer education and awareness that contributes to their understanding of the organic vegetables, but consumer consciousness about the constituents of the food that they consume also explain their familiarity with the organic food. A similar yet exciting result shows that consumers who have read or watched food adulteration news in the last year are more likely to be able to explain the organic food. This suggests that consumer exposure to the (negative) information about the food they consume has an influence on their awareness and understanding of the cleaner food options. This is also because food adulteration is frequently reported in the Pakistani media, as highlighted above.

Consumer willingness to pay the extra price per kilogram for tomatoes produced with the lower use of agrochemicals has a negative sign, which means that consumers who are willing to pay more price premium on cleaner produce are less likely to be able to explain the organic vegetable. Discerningly, this is because of the hypothetical situation where consumers with the knowledge of organic vegetables reported more realistic willingness to pay than those who have less understanding of the organic vegetables. Interestingly, the number of children variable has a negative sign, implying that consumers who have a greater number of children are less likely to be able to explain the organic vegetable. Each additional child reduces the odds of being able to explain the organic vegetable by 3 percent. Conceivably, this is because consumers with a greater number of children have higher household expenses and they are more concerned about the fulfilment of the household basic needs such as food, education and medical cost. This is in line with Roitner-Schobesberger et al. (2008) study which suggests that the buyers of organic vegetables are educated and have high incomes. Nevertheless, Zhang et al., (2018) study indicated that consumer intention to purchase safe vegetables has positive correlation with family food expenditure and children in their household.

This section provides an answer to the second research question of the present research (stated in Chapter 1) which investigates the factors that explain consumer perceptions.

4.5 Conclusions and policy implications

Agriculture in Pakistan is based on intensive farming practices which involve the concentrated use of agricultural inputs, e.g. pesticides and fertilisers. While agricultural intensification improves crop yield and thereby the farming revenues, it has serious implications for human health and the natural environment. The present analysis explores the farmer and consumer perceptions of the intensive farming that is being used in tomato crop in Khushab district of Pakistan and the proposed changes to adopt sustainable agricultural practices to produce cleaner tomatoes. This also includes the investigation of the factors that affect farmer and consumer perceptions with regards to current agricultural practices and the proposed changes. This section summarises the main results and policy implications of this analysis.

Farmer survey results reveal that majority farmers understand that the pesticides and fertilisers they apply in their tomato crop are harmful for their health and the environment. This shows that farmers are cognisant of the risk of intensive farming and might be willing to consider the alternatives to existing farming practices. While farmers generally believe that the proposed reductions in the use of pesticides and fertilisers would decline the tomato crop yield, they do not think that complete elimination of pesticides and fertilisers would result in crop failure. Considering the changes required for the implementation of sustainable agricultural practices to produce cleaner tomatoes, these results are very encouraging. Interestingly, a fraction of respondents in farmer survey believe that the proposed reductions in the use of pesticides and fertilisers would not decrease the tomato crop yield. Similarly, results from consumer survey show that majority consumers are aware of the amounts of agrochemicals being used in tomato cultivation in Khushab, and believe that these agrochemicals have negative health and environmental impacts. *These findings provide the answer to the first research question, outlined in the introduction of this chapter, regarding farmer and consumer perceptions of existing agricultural practices and proposed changes to adopt sustainable agriculture in tomato crop in Khushab.*

Empirical results show that farmers who own their farmland are more likely to believe that tomato crop yield would remain the same with the reduction in the use of pesticides. This is because farmers who own their farmland do not have to pay the rent, and hence may try different options as they have less risk when compared to tenants in case of reduction in the crop yield. Furthermore, they may have multiple sources of income including land rent, which provide them a buffer to take the risk of reducing the pesticides. The policy implication of this result is that farmers with ownership rights might be willing to adopt the proposed changes in existing agricultural practices to produce cleaner tomatoes. Moreover, these farmers could be targeted to encourage and lead the adoption of sustainable agricultural methods.

Findings also show that farmers who have received the training to apply agrochemicals are more likely to have a positive perception of the proposed changes in existing agricultural practices. Most plausibly, this is because they are aware that the proposed reductions would not reduce the yield significantly. Furthermore, these farmers know that the existing agricultural practices involve the concentrated use of agrochemicals which are harmful for human health and the environment. Considering the farmers' limited use and/or access to agricultural extension services, this implies that agricultural extension services play a vital role in educating farmers about the appropriate use of agricultural inputs. This is an important finding with clear policy implications regarding the role of effective agricultural extension services which can facilitate the farming transition towards sustainable agricultural practices in Pakistan. Hence, the relevant departments should strive to enhance the efficiency as well as the outreach of the agricultural extension services.

Investigation of the impact of proposed changes on tomato farm gate price reveal that farm households with a greater number of household members working on farm are more likely to believe that the tomato farm gate price would be unaffected with one-third reductions in the use of pesticides. This suggests that more time and labour investment on tomato crop can offset the impact of proposed reductions in the use of agrochemicals. This result itself has powerful policy implications for tomato crop farmers as well as agricultural extension services.

Empirical analysis of consumer data reveal that households with greater tomato consumption are less likely to be aware of the amounts of agrochemicals farmers use in tomato production. This is possibly because these are large households with greater food expenditures and it is not affordable for them to purchase superior quality food, hence they are not keen about the quality of the food they purchase. However, consumers with an understanding of organic vegetables are more likely to be aware of the amounts of agrochemicals that farmers use in the tomato crop, which indicates that these consumers are possibly more educated, informed and concerned about the quality of the food they consume. Similarly, consumers who read ingredients/nutritional facts of food and those who have a positive perception of their health are more likely to be aware of the amounts of agrochemicals farmers apply in tomato crop.

While the majority of consumers understand that the consumption of organic food is beneficial for their health and the environment, not all consumers could explain the organic vegetable during the survey which indicates a gap in their food safety knowledge. Empirical results show that consumers who have a greater number of children are less likely to be able to explain the organic vegetable which is conceivably due to their higher household expenses and the importance of food affordability rather than a preference for quality. This suggests that large households might be reluctant to buy relatively cleaner food against a price premium. However, consumers with a greater number of years of schooling are more likely to explain the organic vegetables which is an expected result. Likewise, consumers who read ingredients/nutritional facts while shopping the food items are also more likely to decipher the organic vegetables. This shows that the consumers who are keen about the constituents of the food they consume, and those who are conscious about their health retain more information about the production practices.

A similar yet interesting result shows that consumers who have read or watched food adulteration news in the last year are more likely to be able to explain the organic food which indicates that exposure to the information about food safety influences consumer awareness and understanding of the cleaner food options. Considering the empirical results presented in the above section, it can be concluded that consumer education, awareness and food consciousness are the main drivers of the consumer choices of cleaner food options; however, large household size might have a negative effect. This means that education and awareness can pave the way to the uptake of sustainable agricultural practices and thereby the consumption of cleaner food.

The analysis in this chapter provides the answer to the first two research questions of this thesis (outlined inChapter 1), regarding farmer and consumer perceptions of the exiting agricultural practices used in tomato crop and the proposed changes to adopt sustainable agriculture.

The next chapter (Chapter 5) presents farmer preferences for sustainable agricultural practices using DCE the approach.

Chapter 5 Farmer preferences for sustainable agricultural practices

Abstract

Tomato cultivation in Pakistan is based on intensive farming, which entails the concentrated use of agricultural inputs such as agrochemicals and irrigation water. This results in agricultural pollution by infesting soil, water and air among other natural resources which is harmful for human health and the natural environment. Considering the problem of crop intensification and subsequent agricultural pollution, this research proposes to use market-based mechanisms to discourage crop intensification. This requires the changes in current agricultural practices used in tomato cultivation and adoption of sustainable agricultural methods. The changes include the reduction in the use of pesticides and fertilisers, and the adoption of drip irrigation technology. Using the discrete choice experiment (DCE) approach and a primary survey of farm households, this research explores farmers' preferences to adopt the proposed changes in tomato crop production and their willingness to accept (WTA). The WTA estimates help to design compensations to offer farmers for the adoption of proposed changes in existing agricultural practices.

The findings of this study reveal that the tomato farmers prefer the reduction in the use of pesticides and fertilisers, although, by contrast, they disapprove the proposed use of drip irrigation for their tomato crop management. The WTA estimates of reduction in the use of pesticides and fertilisers are positive, however, adoption of drip irrigation has a negative and high WTA. These results imply that the tomato farmers in Khushab are willing to adopt the sustainable agricultural production methods. This suggests that a market-based mechanism to reduce agricultural pollution might be a viable policy option.

Key words: *Discrete choice experiment, incentive, willingness-to-accept (WTA), price premium, health- and environment-friendly.*

5.1 Introduction

Over the past few decades, food demand and production has increased manifold (Boone et al., 2018; Ling et al., 2018) due to increases in world population (Lanz et al., 2018), agricultural technologies including high yield cultivars (Candiotto et al., 2018), production incentives, household incomes (Muhmood et al., 2019), consumption patterns (Tramberend et al., 2019) and international trade (Duarte et al., 2019). In order to meet the growing food demand, farming has increasingly relied on intensive production methods (Boone et al., 2018) that involve greater inputs such as water and agrochemicals. This has resulted in significant stress on land, water, and other natural resources (Chekli et al., 2017; Drysdale and Hendricks, 2018; Tambo and Mockshell, 2018; Duarte et al., 2019; Tramberend et al., 2019); thereby causing pollution, biodiversity loss (Sidemo-Holm et al., 2018; Lanz et al., 2018; Lafuite et al., 2018), and deterioration of human health (Li, 2017; Li, 2018).

Biodiversity and natural resource losses disrupt the delivery of essential ecosystem services to agricultural production (Powell et al., 2015; Lafuite et al., 2018), including pollination (Wilson et al., 2017), pest control (Bommarc et al., 2018), nutrient cycling, and erosion control (Wilson et al., 2017). This problem is more pervasive in developing countries (Li, 2017; Jack, 2017) due to socioeconomic stresses such as poverty and unemployment (Ligon and Sadoulet, 2018), food insecurity (Galeana-Pizaña et al., 2018), limited off-farm income, heavy reliance on agriculture (Ibanez and Blackman, 2016; Eskander and Barbier 2017), and poor environmental compliance. The obvious outcome of such disruptions would have a marked effect on human welfare. The harmful effects of intensive farming on human health and the environment, however, could be offset by promoting the resilience and sustainability of the food system (Powell et al., 2015; Zhou et al., 2019).

This, therefore, calls for the adoption of sustainable agricultural production methods (Tambo and Mockshell, 2018) to preserve ecosystem services in agricultural landscapes (Ward et al., 2018) and safeguard human health (Li, 2017; Li, 2018) while producing food. Sustainable agriculture is a way forward for low-income countries (Zeweld et al., 2017) as it can ensure a harmonious relationship between food production and the natural environment (Candiotto et al., 2018). However, the economic benefits attached to intensive farming, most prominently the increase in crop yield per unit of area, encourage unsustainable agriculture that deteriorates environmental resources as well as human health (Scherer et al., 2018).

Regulations to mitigate agricultural pollution are, however, insufficient (Sidemo-Holm et al., 2018) as well as highly contentious (Petersen and Snapp, 2015). This is why economic incentive schemes are increasingly being proposed as a way to restrict agricultural pollution (Petersen and Snapp, 2015;

Sidemo-Holm et al., 2018). Under these schemes, farmers are compensated for producing environmental public goods (Bell et al., 2016; Banerjee and Conte, 2018), a market-based approach (Ibanez and Blackman, 2016; Chu et al., 2019) to address the issue of agricultural pollution. Farmers are paid to implement various conservation measures that generate ecosystem service benefits for society (Banerjee et al., 2017; Sidemo-Holm et al., 2018).

This study proposes to use economic incentive schemes for the uptake of sustainable agriculture for tomato cultivation in Pakistan. The reason for choosing tomato crop for this research is that it is produced using intensive farming, and tomato is also a commonly used vegetable in almost every household in Pakistan. The idea of economic incentive schemes in this study is based on 'Provider Gets Principle', proposed by Hanley et al. (1998). 'Provider Gets Principle' states that farmers are compensated for activities that help avoid the harm to (or enhance) environmental amenities. Since farming activities could provide environmental amenities which are valuable for the public, farmers are compensated for this service.

The farmer compensation in the present research is the price premium on cleaner tomatoes that will be paid by consumers against farmers' implementation of the proposed changes (reduction in agrochemicals and adoption of efficient irrigation technology to conserve water) in agricultural practices used for tomato cultivation in Khushab District of Pakistan. The price premium on cleaner tomatoes is an economic incentive which can encourage farmers in adopting sustainable agriculture. Using the idea of economic incentive schemes, this research investigates farmer preferences to reduce the use of intensive farming in tomato cultivation in Khushab District of Pakistan.

Agriculture plays a key role in the economy of Pakistan as it employs approximately 42 percent of the labor force and makes up 20 percent of the GDP (GoP, 2018). Pakistani farmers rely heavily on agriculture for food, fodder and their livelihood (Elahi et al., 2018). As a result, they have increasingly used intensive production methods that involve greater input application such as water and agrochemicals (Zulfiqar and Thapa, 2017) to enhance their crops' yields. However, the concentrated use of agricultural inputs including agrochemicals is negatively affecting human health and the environment (Abedullah et al., 2015; Murtaza et al., 2015). For example, there is strong evidence of the presence of agrochemicals residue in Pakistani water (Tariq et al., 2007; Azizullah et al., 2011; Waseem et al., 2014). Similarly, Saeed et al. (2017) claim that there is pesticide residue in the blood samples of people involved in farming in the Vehari District of Pakistan. Shahid et al. (2016) claim that over 500,000 Pakistanis suffer annually from poisoning due to agrochemicals, of which 10,000 died. This being the case, there is obviously an urgent need to address this pervasive problem to avoid further damage.

This state of affairs is due to a lack of awareness of the harmful effects of agrochemicals' use among farming communities, farmers' poor user knowledge of dosages, a lack of training to administer the agrochemicals, and the ineffective enforcement of relevant regulations (Tariq et al., 2007; Azizullah et al., 2011; Saeed et al., 2017). In addition to intensive use of agrochemicals, water use efficiency in Pakistani agriculture is also a serious issue considering the ongoing water scarcity in the country. Over-extraction of groundwater that depletes groundwater resources (Razzaq et al., 2019) and a lack of efficiency in irrigation (Young et al., 2019), among other causes, pose a massive challenge for the sustainable use of water in agriculture. Qureshi (2011) asserts that the water shortage will reach 32 percent of total demand by 2025, which could cause an unprecedented food shortage of 70 million tons.

Using the discrete choice experiment (DCE) approach and primary data gathered from tomato farmers, the present research seeks to understand tomato farmers' willingness to reduce the pesticide and fertiliser use and adopt drip irrigation technology in Khushab. The findings reveal that farmers are willing to adopt some of the proposed changes in existing agricultural practices used in the tomato crop. However, 'willingness to accept' (WTA) estimates for pesticide and fertiliser reductions are positive, showing that farmers need compensation to implement these changes. WTA estimates could be used to set the price premium on cleaner tomatoes which would be a significant step towards the use of market-based approaches for cleaner tomato production and the adoption of sustainable agricultural practices. The creation of economic incentives could help attain a more judicious use of agricultural inputs and thereby enhance environmental compliance in the agricultural sector of Pakistan.

This research investigates the following research questions:

5.1.1 Research questions

1. What are the farmers' preferences to reduce pesticide and fertiliser use and adopt water efficient irrigation technologies?
2. What are the famers' WTA's to adopt the proposed changes in existing agricultural practices used for tomato production?
3. How could the findings of this research inform policy makers in the design of market-based mechanisms to modify the existing agricultural practices?

The chapter is organised as follows: section 5.2 presents a review of literature, 5.3 describes material and methods, 5.4 discusses the results and 5.5 presents the conclusion and policy implications.

5.2 Literature review

This review consists of some of the key DCE studies which are directly related to modification in agricultural practices to make agriculture health- and environmental-friendly and sustainable. The present research investigates the reduction in the use of agrochemicals and adoption of efficient irrigation methods. In this regard, Van den Broeck et al. (2017) reported that farmers prefer fertiliser restriction, but they are reluctant about complete prohibition of agrochemical use, indicating that mitigation of agrochemical use is possible, but not its complete abolition. Similarly, Bennett et al. (2018) reported that farmers prefer lower pesticides' reductions and technical support to mitigate pesticides for coastal wetlands protection.

Prado and Abildtrup (2022) report that participation in pesticide use reduction schemes depend on contract modalities. Furthermore, pesticide use reduction depend highly on landowner profiles in the study area. A study by Lizin et al. (2015) revealed that farmers have higher perceived cost of fertiliser restrictions and identify implications for the crop restrictions. Castillo et al. (2022) explored small-scale farmers' willingness to adopt chemical-free fertilisers and pesticides and found that 40% of them are willing to adopt agrochemicals free inputs.

However, Tur-Cardona et al. (2018) observed that European farmers have a positive preference for a bio-based fertiliser with nitrogen content and relatively lower price compared to chemical fertiliser. In the context of agri-environmental schemes (AES), Kuhfuss et al. (2014) found that a conditional collective bonus in addition to the usual payment for less pesticide-intensive farming can improve farmers' participation and increase the land enrolment for lower costs. Kuhfuss et al. study also claims that the collective bonus increases the participation, and hence a pro-environmental behaviour.

As the present research also investigates farmers' preferences for irrigation, a study by Bell et al. (2014) on cost recovery in the Pakistani context indicates that farmers are willing to pay significantly more than the existing cost of surface water irrigation and place high value on increased surface water reliability. In this regard, Alcon et al. (2019) research on water infrastructure shows that farmers are willing to pay higher water prices to take-up water saving measures including the installation of water meters, while it was also noted that their income and education has a positive impact on WTP. Alcon et al. suggest that farmers are willing to pay for the implementation of water saving measures and younger farmers with higher income and education are more interested in the proposed water saving measures. Likewise, Houessionon et al. (2017) study reveals that farmers are willing to pay for small water infrastructure including drip irrigation and the use of treated wastewater for agriculture.

Bjørnåvold et al. (2022) study indicates that farmers are keen to change existing farming practices, however, they are unclear about the instruments to do it. A related study by Meemken et al. (2017) investigated farmers' preferences for sustainability standards and found that farmers are willing to adopt sustainability standards, with female farmers having a higher preference to adopt sustainability standards than male farmers. On the contrary, Ortega et al. (2016) reported that farmers prefer the existing agricultural practice of growing maize crop instead of legume-maize intercrop recommended for environment-friendly agriculture. Ortega et al. study claims that this is despite legumes' lower labor requirement and soil fertility benefits.

The above reviewed studies which have investigated different aspects of sustainable agriculture. The present research however investigates the reduction in agrochemical use as well as the improvement in irrigation methods for the uptake of sustainable agriculture. Similarly, prior research has predominantly focused on pesticide use reductions, but this research considers the reduction in the use of fertilisers as well.

The next section outlines the methodology used to conduct this research.

5.3 Material and methods

The material and methods used in this analysis are presented and discussed in Chapter 2 and 3.

5.4 Results discussion

5.4.1 Farmer sample characteristics

The sample of farmers that participated in the survey was drawn from the tomato farming community in Khushab district, Pakistan. The average age of farmers is 40 years, and the average formal education is six years (Table 5.1). While most of the farmers have very low literacy, there are few of them with relatively high education. However, the mean of the 'maximum education' (i.e. the years of education of the person with most education in the household, be it the head of the household or not) for farm households is nine years. The reason for collecting data on 'maximum years of education' is that quite often the education of younger household members in rural areas of Pakistan is higher than the education of the household head, which influences household decision-making. The survey data also confirms this contention, i.e. the data on 'maximum years of education' have more observations with 10 years and above education. This is because overtime improvement in educational infrastructure leads to an increased access to education for common people in rural Pakistan.

The net average farm income of tomato farmers in Khushab for one season is 233,828 Pakistani rupees (USD 1,475.77 at 09/07/2019). However, there is a lot of variation in farm income as a fraction of the respondents reported very high income from farming. This is possibly due to the disparity in farm size in the study areas, for example, the maximum farm size is 400 acres which is exceptionally large compared to the average farm size of 16 acres. Nevertheless, this is expected in the rural areas of Pakistan as land reforms have not been implemented in Pakistan due to the political influence of landlords and weak enforcement by the government, hence the land distribution is inequitable. Roughly 73 percent farmers in the sample own the farms and remaining 27 percent are tenants.

Table 5.1: Farmers' socio-demographic characteristics

Characteristics	Mean	St. Dev.	Min.	Max.
Age (years)	40.09	13.71	17	75
Household head education (years)	6.61	3.97	0	22
Maximum education (years)	9.32	3.98	0	22
Farm income (PKRs)	233,828	216,671	10,000	1,500,000
Household size	7.23	3.19	2	22
Farming experience (years)	22.02	13.12	1.5	60
Household members working on farm	3.67	3.23	0	20
Farm size (acres)	16.04	40.55	1	400
Farmer ownership	0.73	0.44	0	1

The average household size in this sample is seven, which is in line with the household size of Khushab District in the 2017 Census of Pakistan. Data shows that on average three household members work on the farm in the study areas, which is common in rural areas of Pakistan considering relatively large average household size and agriculture being the main source of livelihood. The average farming experience in the study sample is 21 years, indicating that the study participants have significant farming experience.

5.4.2 DCE estimates

This section presents a discussion on discrete choice models estimated to analyse the determinants of farmers' choices, from which their preferences for adopting the proposed changes in current agricultural practices used in tomato cultivation are derived. The proposed changes are reduction in the use of agrochemicals, e.g. fertilisers and pesticides, and adoption of drip irrigation technology. Results presented in this section are obtained from the mixed logit model estimated in preference-space and price-space.

a. Uncorrelated coefficients in preference-space

A mixed logit model is specified in preference-space with random coefficients and no correlation across coefficients. This model does not allow for random scale, as it is not possible to separate scale heterogeneity from correlation in preference heterogeneity (Hess & Train 2017). A model with fully correlated coefficients is presented later. The coefficient for price premium is fixed (i.e. it is a point estimate, as in a non-random coefficient) and the remaining coefficients are specified to be normally distributed. While assuming the constant marginal utility of money is unrealistic, the reason for using a fixed price is to be able to obtain the finite moments of farmer WTA. An alternative way to bypass this problem is to estimate the model directly in price-space, as advised by Daly et al. (2012). Such a model is presented and discussed later in this section. This model is estimated with 1000 Halton draws and the results include means and standard deviations of the coefficient distributions, except for the price which is fixed. The estimates are obtained using a simulated maximum likelihood approach. The DCE attributes are either desirable or undesirable, depending on the views and tastes of the respondents which are farmers in this case. Since this research investigates farmer preferences to adopt the proposed changes in current agricultural practices used in tomato cultivation; the DCE attributes in this analysis signify the proposed changes such as adoption of drip irrigation, fertiliser reductions (by 33% and 50%) and pesticide reductions (by 25% and 33%). Hence, the variables of the models presented below are the attribute levels demonstrating the proposed changes to the status-quo.

Table 5.2: Model in preference-space with uncorrelated coefficients

Base model			
Attribute	*Parameter*	*Estimate*	*St. error*
Status-quo	Mean of coeff.	-11.472	2.787
	St. dev. of coeff.	12.936	3.137
Drip irrigation	Mean of coeff.	-3.007	0.338
	St. dev. of coeff.	2.753	0.343
33% less fertilisers	Mean of coeff.	0.352	0.149
	St. dev. of coeff.	0.074	0.312
50% less fertilisers	Mean of coeff.	0.429	0.148
	St. dev. of coeff.	0.197	0.536
25% less pesticides	Mean of coeff.	0.227	0.152
	St. dev. of coeff.	0.403	0.442
33% less pesticides	Mean of coeff.	0.573	0.161
	St. dev. of coeff.	0.540	0.316
Price premium	Mean of coeff.	0.112	0.021
Log likelihood	-718.118	-	-
No. of parameters	13	-	-
Observation	4514	-	-
N	251	-	-

Coefficients of the variables reflect the value of the proposed changes relative to the current agricultural practices. The coefficient (alternative specific constant) for the status-quo variable shows farmer (dis)utility from the existing agricultural practices. The coefficient for the drip irrigation reflects the value of drip irrigation technology relative to the furrow irrigation. The coefficient for the first fertiliser variable (33%) captures the extra utility farmers derive from smaller reductions in fertilisers, while the coefficient for the second fertiliser variable (50%) shows the extra utility associated with the greater fertiliser reductions. Likewise, the two coefficients of the pesticide variables capture the utility associated with smaller and greater reductions in the use of pesticides.

Table 5.2 gives estimation results for a mixed logit model in preference-space with uncorrelated coefficients. Model estimates are generally reasonable and the estimated means of the coefficients have expected signs. All else equal, status-quo is considered worse than the proposed changes by the majority of the farmers which implies that farmers prefer proposed changes and dislike existing agricultural practices when compared with the alternatives offered in the choice tasks. Similar results have been reported in previous research (Van den Broeck et al., 2017; Oyinbo et al., 2019; Alcon et al., 2019; Gao et al., 2019; Geussens et al., 2019). The mean and standard deviation of the status-quo variable imply that roughly 82 percent of the population place a negative value on the status-quo relative to the proposed changes.

Similarly, drip irrigation is considered worse than furrow irrigation (existing irrigation methods) by the majority of the farmers. The negative sign of the drip irrigation coefficient shows farmers' disutility for its adoption, unlike Houessionon et al. (2017) who show farmers' positive preference for drip irrigation. The mean and standard deviation of the drip irrigation coefficient show that almost 86 percent of the population place a negative value on the drip irrigation relative to the furrow irrigation. The estimated standard deviations of status-quo and drip irrigation coefficients are both significant and large relative to their means, which implies that there is a substantial amount of heterogeneity in farmer preferences for these two attributes. However, the choice of distribution could also influence the results.

Farmers prefer the proposed reductions in the use of fertilisers and pesticides to their current amounts. Interestingly, the proposed reductions in the use of fertilisers and pesticides are valued at an increasing rate. For example, the average utility associated with greater amounts of fertiliser and pesticide use reductions (0.429 and 0.573) is higher than that for smaller amounts of fertiliser and pesticide use reductions (0.352 and 0.227), respectively. The standard deviations of the coefficients of fertiliser and pesticide use reductions are lower than those of the status-quo and drip irrigation. This indicates that farmers are more similar in their desire for reduction in the use of fertilisers and pesticides than in their value for status-quo and drip irrigation. Furthermore, this means that farmers in study areas are willing to adopt the proposed reductions in the use of agrochemicals in their tomato production if their yield do not diminish significantly (an hypothesis of the survey) which is in line with the results of previous research such as Oyinbo et al. (2019) and Gao et al. (2019), but contrasts with Kuhfuss et al. (2016), Van den Broeck et al. (2017). However, Bennett et al. (2018) results show farmers' dislike for the reduction in the use of agrochemicals.

The coefficients for reducing fertiliser utilisation by 33% and 50% are random, with each of them following an independent normal distribution. This could lead to situations where the effect of fertiliser reductions are not monotonic, for example, that the effect of a 50% reduction is smaller than the effect of a 30% reduction. As we estimated the mean and standard deviation of each of these coefficients (see Table 5.3), it is possible to calculate the probability of those situation, in particular[8]: $P(\beta_{Fert-50\%} < \beta_{Fert-30\%}) = 35.72\%$. In an analogous way, we can calculate the same probability for the reduction of pesticide not following a monotonic trend, in particular: $P(\beta_{Pest-33\%} < \beta_{Pest-25\%}) = 27.67\%$.

The probability of observing non-monotonic preferences for fertiliser and pesticide reductions are not negligible, which points to two possible explanations. First, it could be that some individuals have non-monotonic preferences. For example, they would like to have a conservative reduction in fertiliser and/or pesticide, but they are worried about a bigger reduction impacting their yields. The second possibility is that the non-monotonic preferences are simply a spurious consequence of the coefficients following uncorrelated normal distributions.

To assess which of the two possible explanations is more likely to be correct, a model was estimated allowing for correlation between fertiliser random coefficients, and between pesticide coefficients as well. If the probability of non-monotonic preferences maintains or increases its magnitude when allowing for correlation, this points to the non-monotonic preferences being a true behaviour of participants. On the other hand, if the probability of non-monotonic preferences decreases when allowing for correlation, this points to the non-monotonic preferences only being an undesirable side-effect of the coefficients following independent normal distributions. The new model with correlated coefficients leads to[9] $P(\beta_{Fert-50\%} < \beta_{Fert-30\%}) = 40.48\%$ and $P(\beta_{Pest-33\%} < \beta_{Pest-25\%}) = 7.45\%$. This points to a big part of the population of farmers (around 40.48%) being wary of a big (50%) reduction on the use of fertilisers, and who would feel more comfortable with a milder reduction of only 30%. On the other hand, farmers do show a monotonic preference for pesticide reduction, with most (92.55%) of farmers preferring a 33% reduction of pesticide over a 25% reduction. A table summarising the parameter estimates and level of fit of the model with correlated coefficients can be found in Appendix – E.

Despite the model with correlation providing more information than the model without correlation, the fit of the model is not significantly better. A likelihood ratio test indicates that the fit is not significantly better than the model without correlation at 95% confidence[10].

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[8] The calculation is simply the probability of $P(X \leq 0)$ where $X = (\beta_{Fert-50\%} - \beta_{Fert-30\%}) \sim N(0.429 - 0.352, \sqrt{0.197^2 + 0.074^2})$

[9] These calculations were performed using simulation. 200000 draws were generated for each of the bivariate normal (fertiliser and pesticide coefficients), and the proportion of cases where $\beta_{Fert-50\%} < \beta_{Fert-30\%}$ and $\beta_{Pest-33\%} < \beta_{Pest-25\%}$ was calculated.

[10] $-2(LL_{uncorrel} - LL_{correl}) = 4.496 < \chi^2_{df=2;\,\alpha=5\%} = 5.991$

Furthermore, a model with full correlation between random coefficients was estimated, i.e. a model were all coefficients but price's were correlated. This model reached a log likelihood value of -707.46. Once again, a likelihood ratio test indicates that the fit is not significantly better than the model without correlation at 95% confidence (test value was 21.316 while the table value was 24.996, with 15 degrees of freedom). The parameter estimates, as well as the main indicators of fit of this model are presented in the Appendix – E (E1-E3). Given the negligible advantage that considering correlation between parameters provides, all future models will be estimated without correlation.

Table 5.3: Model in preference-space with uncorrelated coefficients & interactions

Model with attribute interactions			
Attribute	*Parameter*	*Estimate*	*St. error*
Status-quo	Mean of coeff.	-11.512	2.799
	St. dev. of coeff.	12.817	2.931
Drip irrigation	Mean of coeff.	-2.984	0.333
	St. dev. of coeff.	2.727	0.338
33% less fertilisers	Mean of coeff.	0.360	0.149
	St. dev. of coeff.	0.074	0.330
50% less fertilisers	Mean of coeff.	0.423	0.147
	St. dev. of coeff.	0.116	0.573
25% less pesticides	Mean of coeff.	-0.355	0.280
	St. dev. of coeff.	0.283	0.644
33% less pesticides	Mean of coeff.	0.050	0.281
	St. dev. of coeff.	0.512	0.314
Price premium	Mean of coeff.	0.111	0.021
25% less pesticides × edu.	Mean of coeff.	0.083	0.034
33% less pesticides × edu.	Mean of coeff.	0.075	0.035
Log likelihood	-714.380	-	-
No. of parameters	15	-	-
Observation	4514	-	-
N	251	-	-

A second model in preference-space with uncorrelated coefficients is also estimated, but this time adding interactions between the attributes and respondents characteristics to allow for systematic variation of preferences. However, few attribute interactions are found to be significant and meaningful to explore the observed interpersonal heterogeneity in farmer preferences (Table 5.3). The specification search process for the demographic interaction terms involved a *backward* process. Starting with a large model with all possible interactions (alternative attributes x respondent characteristics), the least significant parameter was removed, and the model estimated again. Then the process was repeated until reaching a model where all parameters: (i) had the expected sign, i.e. price premium had to be positive; (ii) reached a minimum level of significance of 95%, or measured direct effects of attributes (without any interactions, both for the mean and standard deviation parameter). The initial model for the backward process is presented in Appendix – F.

Unlike the attributes' coefficients which are random, the interaction terms have fixed coefficients. There are other ways (e.g. allowing scale heterogeneity) to accommodate observed interpersonal heterogeneity in respondent choices as well, but this research relies on using the demographic interactions of attributes as this method is more suitable to generate context specific information, and hence give more meaningful policy suggestions which is the main objective of this research.

As the inclusion of attribute interactions does not alter the value of coefficients without interactions, the discussion is restricted to interactions only. The coefficients of the interaction of education with both pesticide variables capture the extra utility educated farmers associate with the decrease in pesticides by 25% and 33% of their current use. This implies that educated farmers place a relatively high value on the proposed pesticide reductions. In this regard, Gao et al. (2019) also reported that education influences farmer preferences for pesticide reductions. This means that education can play a positive role in the adoption of sustainable agricultural practices in study areas. The finding has powerful policy implications for the success of possible interventions to reduce intensive farming in low-income low-literacy rural settings in Pakistan.

Table 5.4: WTA from models in preference-space with uncorrelated coefficients

Base model								
	Sample				Population			
Attribute	Mean		St. Dev.*		Mean		St. Dev.	
Drip irrigation	-26.89	(5.16)	18.45		-26.85	(3.02)	24.58	(3.06)
33% less fertilisers	3.15	(1.34)	0.15		3.14	(1.33)	0.66	(2.79)
50% less fertilisers	3.84	(1.41)	0.45		3.83	(1.32)	1.76	(4.79)
25% less pesticides	2.03	(1.37)	1.13		2.03	(1.36)	3.6	(3.95)
33% less pesticides	5.12	(1.48)	1.66		5.12	(1.44)	4.82	(2.82)
Model with attribute interactions								
	Sample				Population			
	Mean		St. Dev.*		Mean		St. Dev.	
Drip irrigation	-26.91	(5.18)	18.37		-26.88	(3.00)	24.57	(3.05)
33% less fertilisers	3.24	(1.35)	0.14		3.24	(1.34)	0.67	(2.97)
50% less fertilisers	3.81	(1.41)	0.25		3.81	(1.32)	1.05	(5.16)
25% less pesticides	-3.19	(2.60)	0.73		-3.2	(2.52)	2.55	(5.80)
33% less pesticides	0.45	(2.52)	1.56		0.45	(2.53)	4.61	(2.83)
25% less pesticides × edu.	0.75	(1.36)	-		0.75	(0.31)	-	-
33% less pesticides × edu.	0.68	(1.47)	-		0.68	(0.32)	-	-
* st.dev. of sample WTA does not have s.e., as it is calculated from point estimates for each individual								

Table 5.4 shows the WTA distributions derived from the model in preference-space, including the estimated mean and standard deviation of the WTA for each attribute, except the interaction terms (which have fixed coefficients and hence only means of the WTA's are reported). For preference-space models, a convenient distribution is specified for the coefficients and WTA is derived from the estimated distribution of coefficients. In this case, as the coefficients follow normal distributions,

except for the price premium coefficient that is a point estimate, all WTA measures also follow normal distributions.

The WTA values in Table 5.4 are presented both for the sample and the population. The values for the sample are calculated based on the individual level parameters. First, individual level parameters are calculated for each individual in the sample following the procedure described by Train (2009) Chapter 11. Then, the mean and standard deviation are calculated from the list of values, while the standard error of the mean is calculated using the corresponding STATA willingness to pay command, given in the code appendix. In the case of the population WTA values, these are calculated simply by dividing the mean and standard deviations of attributes reported in Tables 5.3 and 5.4 by the price coefficient. This is correct as the WTA formula is $WTA_x = \frac{\beta_x}{\beta_{price}}$, where $\beta_x \sim N(\mu_x, \sigma_x)$, and β_{price} is a fixed parameter. Therefore, $WTA_x \sim N\left(\frac{\mu_x}{\beta_x}, \frac{\sigma_x}{\beta_x}\right)$. Similarly, $s.e.\left(\frac{\mu_x}{\beta_x}\right) \approx \frac{s.e.(\mu_x)}{\beta_x}$ and $s.e.\left(\frac{\sigma_x}{\beta_x}\right) \approx \frac{s.e.(\sigma_x)}{\beta_x}$, while this ignores the standard error of β_x, it is a reasonable approximation for the error of the mean and standard deviation of the WTA.

Both the population and sample WTA follow the same trend. The standard deviations of the population values tend to be larger than the standard deviation of the sample values, which is to be expected as they represent the whole population as opposed to a small sample. However, as the trends are similar between sample and population WTA, only the sample level WTA are discussed below.

The estimated distributions of WTA shows a large standard deviation for drip irrigation, indicating that a significant fraction of survey participants is willing to forgo a substantial amount of money to avoid the adoption of drip irrigation technology. Similarly, the second variable of fertiliser reductions (50%) also has relatively large standard deviation, implying that a segment of farmers is willing to accept a substantial amount of money to reduce the greater use of fertilisers in tomato crop. While this reflects a high degree of preference heterogeneity, it may also be a result of the choice of distributions for the coefficients and hence WTA, as Hole and Kolstad, (2012) indicated.

The implied distribution of WTA from preference-space model shows that farmers have negative WTA for drip irrigation technology. Research by Meemken et al. (2017) and Geussens et al. (2019) also studies WTA for drip irrigation, but unlike the present research, they find that farmers do not need compensations to implement drip irrigation, instead they are willing to pay to implement the desired changes. However, WTA estimates show that farmers are willing to forgo 26.89 rupees per kilogram of tomatoes from their earnings to avoid the adoption of drip irrigation technology. This is a large amount that farmers are willing to sacrifice to avoid drip as it is more than the average farm gate price of tomatoes per kilogram (10-15 rupees/kg reported by tomato farmers in May 2018). This indicates that drip irrigation is considered worse than the furrow irrigation and farmers derive greater disutility from its adoption. While this is mainly due to the high installation cost of drip technology and uncertainty in land tenure, a more compelling case is the private investment on drip irrigation when the benefit from water saving is social in nature. Hence, farmers dislike this offer and choose to reject it. This could however also be due to low farm gate price of tomatoes and already high production costs that farmers face due to expensive inputs such as imported seeds and agrochemicals.

As expected, farmers have positive WTA's for fertiliser and pesticide reductions. Interestingly, similar to the utility coefficients, farmers WTA's for greater fertiliser and pesticide use reductions are higher. While farmer WTA's for fertiliser and pesticide use reductions exhibit increasing rate, farmer WTA's are higher for greater reductions in pesticides than that for greater reductions in fertilisers. The standard errors of the WTA also show that there is some variability in WTA's for drip irrigation and first pesticide variables.

In addition to the mean and standard deviation of farmer WTA's for the proposed changes, their percentile distribution is also presented in Table 5.5 and Table 5.6. The percentile distribution of farmer WTA's is derived using the individual-level estimates of the model, i.e. these are the sample quantiles. Except for the 90th percentile, the farmer WTA for the adoption of drip irrigation is negative and the positive value at the 90th percentile is also very small. However, farmer WTA's for fertiliser and pesticide use reductions are not only positive, but they are increasing throughout. While the increase in farmer WTA for fertiliser and pesticide reductions is gradual, it is higher for the greater fertiliser and pesticide use reductions (second variables of reduction) than that for smaller reductions (first variables of reductions).

Table 5.5: Percentiles of WTA distribution based on individual level coefficient estimates

Attributes	10th	20th	25th	50th	75th	80th	90th
Drip irrigation	-43.58	-42.51	-42.08	-34.70	-14.88	-9.35	0.39
33% less fertilisers	3.04	3.09	3.10	3.15	3.21	3.23	3.31
50% less fertilisers	3.33	3.60	3.65	3.83	4.02	4.09	4.30
25% less pesticides	0 .82	1.37	1.54	2.04	2.54	2.68	3.30
33% less pesticides	3.53	4.17	4.33	4.99	5.93	6.28	6.88

The percentiles calculated using the population coefficients offer a slightly different perspective. First, values are of bigger magnitude. This is due to the individual level parameters not covering the tails of the distribution of the random coefficients. Second, the 10th to 25th quantiles of 50% fertiliser reduction are smaller than those for 33% fertiliser reduction for the population quantiles. This effect is lost on the individual level parameters because individuals' with large posteriors (i.e. individual level parameters) for 33% reductions of fertiliser, also tend to have large magnitude posteriors for 50%

reductions, so the effect is masked. Finally, the quantiles for the reduction of pesticide present negative values for the lower quantiles in the population, unlike the values in the individual level parameters. Again, this is due to the individual level parameters not covering the tails of the distribution of the random coefficients.

If the focus is on the larger population of farmers, then the quantiles for the population parameters should be considered. If instead policy implications want to be derived exclusively for the individuals in the sample, then the quantiles from the individual-level parameters offer a better perspective.

Table 5.6: Percentile of WTA distribution based on the population level coefficient estimates

Attributes	10th	20th	25th	50th	75th	80th	90th
Drip irrigation	-58.35	-47.54	-43.43	-26.85	-10.27	-6.16	4.65
33% less fertilisers	2.29	2.58	2.69	3.14	3.59	3.70	3.99
50% less fertilisers	1.57	2.35	2.64	3.83	5.02	5.31	6.09
25% less pesticides	-2.58	-1.00	-0.40	2.03	4.46	5.06	6.64
33% less pesticides	-1.06	1.06	1.87	5.12	8.37	9.18	11.30

The above presented results provide an answer to the third research question of the present research (stated in Chapter 1) which investigates the farmer preferences and WTA to reduce pesticide and fertiliser use and adopt efficient irrigation technologies in the tomato crop in Khushab. The answer is that farmers are willing to reduce fertiliser and pesticide without requiring compensation for it, as long as yields are not significantly reduced.

While mixed logit is a commonly used model specification in discrete choice analysis, there are some practical problems associated with its estimation which remain unsolved (Sillano and Ortuzar, 2005). For example, there is a debate on the validity of implied WTA estimates from mixed logit models estimated in preference-space. Since the cost coefficient enters the denominator of the WTA, its distribution determines the distribution of WTA. As Daly et al. (2012) elaborated in their paper, this may be correct in the theory, but it can be problematic in practice as a value of the cost coefficient that is close to zero can result in a very large WTA. Furthermore, there might be a problem of lack of moments of the WTA distribution for a given distribution of the cost coefficient which undermines the value of results from a policy appraisal point of view.

According to Daly et al. (2012), many commonly used distributions for the cost coefficient imply that the distribution of WTA has undefined or infinite moments. Authors claim that the simulation method to deal with the problem of lack of moments of WTA (used by some researchers) only masks the problem, and provides incorrect finite moments. In this regard, Sillano and Ortuzar (2005) argue that estimating individual-level parameters is a useful procedure to circumvent the problem which the present research has attempted. Daly et al. (2012) however think that the most straightforward solution to this problem is to estimate the model in WTA or price-space. Therefore, the present research has adopted the estimation in price-space where the distribution of WTA is estimated directly rather than deriving from the estimated coefficient distributions.

b. Uncorrelated WTA in price-space

A model is estimated in price-space in such a way that the coefficient of each non-price attribute is the product of the WTA for that attribute multiplied by the coefficient of price, and this model allows for random scale. All variables are specified to be normal, except for the price premium which is log-normal. In this model, the WTA's are assumed to be uncorrelated over attributes. Uncorrelated WTA estimates imply correlated coefficients which is due to the common influence of the price premium coefficient on all other coefficients (Train and Weeks, 2005). The estimates are presented in Table 5.7. The log-likelihood of the model in price-space is higher than the log-likelihood of the model estimated in preference-space, which implies that model in price-space has a better model fit than the model in preference-space. This contrasts with the results reported by Train and Weeks (2005), Sonnier et al. (2007), Hole and Kolstad, (2012) and Coffie et al. (2016), while Scarpa et al. (2008) find that the price-space model fits their data better. However, this is also because the model in price-space has one more random coefficient than the model in preference-space.

Table 5.7: Model in price-space with uncorrelated WTA's

Attribute	*Parameter*	*Estimate*	*St. error*
Status-quo	Mean of coeff.	-65.06	13.701
	St. dev. of coeff.	89.393	16.949
Drip irrigation	Mean of coeff.	-21.801	3.187
	St. dev. of coeff.	20.078	2.501
33% less fertilisers	Mean of coeff.	4.242	1.005
	St. dev. of coeff.	1.430	0.594
50% less fertilisers	Mean of coeff.	3.632	0.825
	St. dev. of coeff.	4.115	1.067
25% less pesticides	Mean of coeff.	1.315	0.617
	St. dev. of coeff.	4.738	0.604
33% less pesticides	Mean of coeff.	5.588	1.011
	St. dev. of coeff.	5.066	1.439
Scale	Mean of coeff.	1.428	0.242
	St. dev. of coeff.	1.174	0.289
Log likelihood	-710.781	-	-
No. of parameters	14	-	-
Observation	4514	-	-
N	251	-	-

The model in price-space shows that the means of the coefficients have the expected signs. Moreover, the estimates are consistent in terms of signs and significance across preference-space and price-space models. Comparing Table 5.4 and 5.7, there is not much difference between the distribution of WTA from model in price-space and the implied distribution of WTA from model in preference-space.

Furthermore, unlike Train and Weeks (2005), there is still prevalence of large standard deviations for WTA's from the model in price-space. This means that there is a nontrivial share of people with large WTA's. Hole and Kolstad, (2012) also report high standard deviation of WTP measures from their model in price-space. Implied ranking of the means of the WTA distributions from model in preference-space and model in price-space do not change significantly, as reported by Hole and Kolstad, (2012).

As mixed logit model specification allows for unobserved interpersonal heterogeneity, models in preference- and price-space reveal significant unobserved variation (across individuals) in various attributes as standard deviations of the random terms are significantly different from zero. This indicates that there is a high dispersion in the utility of price premium and (dis)utility of proposed changes due to unobserved tastes.

c. Results discussion

Since this is applied research and its aim is to generate policy suggestions to adopt sustainable agricultural practices, it is important to put the findings in the research context and discuss their meanings and policy implications. Results of the present research are interesting and reveal important insights regarding farmer preferences to adopt the proposed changes in current agricultural practices to produce cleaner tomatoes.

Results show that farmers are reluctant to adopt the drip irrigation technology and they are willing to forgo a significant amount of earnings to avoid the adoption of drip. While high installation cost of drip technology and uncertainty in land tenure deter tenant farmers from committing to the long-term investments necessary for the adoption of drip irrigation, private investment on drip irrigation when the benefit from water saving is social is also a barrier which discourage farmers to adopt it. In addition, since the cost of water in terms of bill is fixed, there is no penalty on greater water use. Hence, there is no incentive in the adoption of drip irrigation for farmers. However, this could also be due to low farm gate price of tomatoes and already high production costs that farmers face due to expensive inputs such as imported seeds and agrochemicals.

This is an important finding, since it implies that insecure land tenancy is also an impediment to the adoption of efficient irrigation technologies amongst tomato farmers in Khushab. However, farmers who own the farmland are also unwilling to invest in drip irrigation technology due to its higher installation and maintenance cost as considering the relatively low farm gate price of tomatoes, this is too high an investment. The policy implication of this result is that there is a need to design some incentive for farmers to encourage the uptake of drip technology as its adoption is extremely crucial for the judicious and efficient use of irrigation water. For example, a subsidy for drip technology may enhance its adoption and it can also offset the advantage large households enjoy in rural areas due to abundance of cheap labour for maintaining furrow irrigation.

Concerning agrochemicals, farmers are not only willing to reduce the use of pesticides and fertilisers in their tomato cultivation, but they also prefer greater amounts of fertiliser and pesticide use reductions. This shows that farmers are cognisant of the overuse of agrochemicals and place a positive value on their significant reductions. Furthermore, farmers are more similar in their desire for reduction in the use of fertilisers and pesticides than in their disutility for drip irrigation. Nevertheless, farmer WTA's for greater fertiliser and pesticide use reductions are higher which indicates farmer understanding of the proposed reductions in agrochemical use, and hence their valuation. It is interesting to note that farmer WTA's for greater reductions in pesticides is higher than those for greater reductions in fertilisers, which indicates that farmers demand relatively higher compensation for pesticide reductions.

An important caveat to farmers' willingness to reduce the use of agrochemicals is that it is conditional to maintaining the current yield of their fields. This should be possible, as the proposed reductions would bring the use of agrochemicals to their recommended values (as current use exceeds the recommended amounts).

An obvious question however is that if farmers prefer the reduction in the current amounts of agrochemicals, why do they practice their intensive use? The main reason behind this is that farmers do not want to risk a decrease in their tomato crop yields, and hence lose revenue. Insignificant market share of cleaner food production and farmer lack of education also contribute to the problem. A market based mechanism that this research proposes and government role to implement the proposed changes could be a viable solution to this problem. Government can facilitate the adoption of sustainable agricultural practices and the development of a cleaner food production market, a theme that the present research advances.

The above findings clearly indicate that the proposed changes in current agricultural practices used in tomato cultivation, and hence the adoption of sustainable agriculture are viable. The proposed changes could enhance the farmer as well as consumer welfare as they have positive implications for human health and the natural environment in addition to a potential increase in the farm gate price. Policy makers can support farmers in the production and supply of cleaner tomatoes by developing their technical capacity through training on cleaner tomato production. This could be achieved by improving the efficiency and outreach of the local agricultural extension service, which is very poor in most of the areas in Pakistan. Similarly, investing in the improvement of the supply chain of sustainably sourced tomatoes could significantly enhance farmer access to retailers and increase their revenue.

Lastly, a trustworthy and reliable food certification system would not only be instrumental in developing a market-based mechanism for cleaner food production in a regulation driven command-and-control environment, but it will also help farmers in marketing their produce more effectively.

5.5 Conclusion and policy implications

Conducting a DCE study with rural farmers in a developing country context is a massive task, involving not only the cumbersome process of data collection under difficult circumstances, but also the challenges inherent in understanding and interpreting *choices* in a social norms driven tribal society. However, as the findings of this study show, this effort has been ultimately justified. While it informs the implementation of the DCE methodology in similar contexts, it also uncovers the compelling social phenomena driving individual preferences in a low-income, low-literacy rural setting. The understanding of the preferences pattern and its underlying causes emerging from these insights thus generates a powerful set of policy implications regarding the use of market-based mechanisms in a regulation driven command-and-control environment.

Indeed, the DCE, as a non-market valuation tool, has helped in the discovery and quantification of the trade-offs that farmers are making regarding the attributes of the proposed changes in existing agricultural practices. This has facilitated in understanding the farmer preferences, and hence their valuation of different sustainable tomato production policy scenarios, which clearly signifies that DCE could be used to generate the empirical evidence to design food and agricultural policies for the rural areas of Pakistan where choices are often communal and driven by social norms. This means that the DCE, as a methodology, is an equally powerful and appropriately robust tool for applied research in a low-income, low-literacy rural setting in a developing country context, provided that it is carefully designed and implemented.

Since the DCE application in this analysis also uncovers some *socio-demographic attributes* that drive the respondents' choices in the study area, it shows the power of the methodology to provide context-specific information for policy makers to design the policies. More generally, this means that the power of DCE as a tool can also be exploited in similar customs-driven rural tribal societies, where decision-making is influenced by social-norms and communal considerations in addition to pure profit motives. The analysis in this research is carried out by estimating a mixed logit model in preference-space and price-space. Results are generally reasonable and similar across both utility specifications. Preference- as well as price-space model specifications show the prevalence of preference heterogeneity, as expected. Overall, the mixed logit model in price-space fits the data better than the model in the preference-space. This was to be expected, as the model in price-space uses a full set of random coefficients, while the model in preference-space uses a non-random price coefficient to guarantee the well-behaved distributions for the WTA values.

While this study informs the methodology as well, the main aim of it is to investigate the use of market-based mechanisms (e.g. economic incentive schemes) to encourage farmers to adopt sustainable agricultural practices in an 'intensive farming system', where agricultural compliance to health and environmental standards is thin. In this context, economic incentive schemes can encourage farmers to adopt the proposed changes in current agricultural practices, reduce the intensive use of agrochemicals, and advance the improvement of irrigation water efficiency in a cost-effective way.

The findings reveal that farmers are willing to adopt some of the proposed changes in existing agricultural practices for the tomato crop. This includes reduction in pesticide and fertiliser use, although farmers are disinclined to adopt drip irrigation technology owing to its high cost and uncertainty of the land tenures which results in the insecurity of any potential investment in drip irrigation. The land tenures in study area are uncertain due to temporary and undocumented contracts in addition to shorter length of tenancy which deter tenants from committing to the long-term investments necessary for drip irrigation technology. As uncertainty of land tenure is due to informal land tenancy regimes and an agency cost for farmers, this means that the government intervention to facilitate more formal (documented) land tenancy arrangements can contribute towards the attainment of a more sustainable food production system, while at the same time empowering tenant farmers and removing administrative inefficiencies.

Needless to say, the empowerment of tenant farmers would facilitate the farming transition to sustainable agriculture in an entirely different way. This result has an important implication: that the feudal social structure and land ownership rights themselves function as direct impediments to the adoption of efficient irrigation technologies, and hence the sustainable farming practices. The result implies, therefore, that policy makers must pay adequate attention to *social structure and land ownerships* while designing agricultural policies in Pakistan, as this has a strong bearing on the outcomes and hence the success of policy interventions.

Significant socioeconomic covariates, as attribute interactions, were also incorporated in utility functions to assess their impact on choice probabilities as well as the welfare estimates of respective attributes. Results show that the interaction of farmer education with pesticide reduction variables are significant with a positive sign, which implies that educated farmers are more likely to prefer reduction in the use of pesticides. This indicates that farm households with greater education have higher chances to adopt the proposed changes in current agricultural practices used in tomato cultivation in Khushab. These findings provide a key entry point for policy makers to enhance the uptake of proposed changes amongst tomato farmers, with the obvious vehicle for their delivery being agricultural extension service, which can play a powerful role by educating farmers regarding the use of sustainable agricultural practices.

The above findings answer the first research question, outlined in the introduction section of this chapter, regarding the farmers' preferences to reduce pesticide and fertiliser use and adopt efficient irrigation technologies.

The prevalence of large standard deviations of WTA estimates indicate that a significant fraction of survey participants require large amounts of money to adopt the proposed changes, which means there is preference heterogeneity. Nevertheless, this could be due to the use of normal distributions for the random coefficients, yet it still points out to wide heterogeneity in preferences. The estimated distributions of WTA shows that farmers have negative WTA for drip irrigation technology, indicating that farmers are willing to forgo some earnings to avoid the adoption of drip irrigation technology. The high installation cost of drip technology, uncertainty in land tenure that deter tenant farmers from committing to the long-term investments necessary for the adoption of drip irrigation, social benefit from water saving at the cost of farmers' private investment, and fixed cost of irrigation water are the main factors responsible for farmers' negative WTA for drip irrigation technology. Nevertheless, low farm gate price of tomatoes and high production costs could also discourage farmers to adopt drip irrigation. As expected, farmers have positive WTA's for fertiliser and pesticide reductions and their WTA's for greater fertiliser and pesticide use reductions are higher. Moreover, farmer WTA's are higher for greater reductions in pesticides than that for greater reductions in fertilisers.

These results regarding farmer WTA estimates answer the second research question posed in the introduction section of this chapter.

Farmers' preference for the proposed changes in existing agricultural practices (except drip irrigation which is due to uncertain land tenancy and higher cost) and their willingness to adopt those indicate the scope for sustainable agricultural practices in the study areas. These findings suggest that market-based approaches might be a successful policy option to solve the problem of agricultural pollution in Pakistan, while simultaneously reducing administrative and regulatory burden. Market-based approaches can complement, and in some cases substitute, existing food safety regulations, saving huge health and environmental costs to the Pakistani economy. More generally, results demonstrate that market-based mechanisms might be viable in various developing countries which have instead traditionally relied upon regulatory measures, thus justifying the initial motivational hunch to conduct this study.

This part of the conclusion answers the third research question that how the findings of this research could inform policy makers in the design of market-based mechanisms to modify the existing agricultural practices?

In addition to the advice rendered to policy makers, findings of this study also provides actionable information to consumers and food businesses. For example, welfare estimates can inform businesses interested in exploiting market niches in the cleaner food production sector in Pakistan. These businesses can invest in cleaner food and sell relatively cleaner produce against higher premiums in a more targeted market consisting of relatively affluent urban areas.

Overall analysis presented in Chapter 5 answers the third research question outlined in the introduction chapter of this thesis (Chapter 1).

The next chapter (Chapter 6) discusses consumer preferences for sustainable agricultural practices using the DCE approach.

Chapter 6 Consumer preferences for sustainable agricultural practices

Abstract

There is an intensive use of agricultural inputs such as agrochemicals and irrigation water in tomato cultivation in Khushab Pakistan, which has serious implications for human health and the natural environment. The present research proposes to use market-based mechanisms to modify the current agricultural practices used in tomato cultivation and adopt sustainable agriculture. For this purpose, this study seeks to understand consumer preferences and willingness to pay (WTP) for reduction in the use of pesticides and fertilisers and adoption of efficient irrigation technologies in tomato cultivation. The analysis is carried out using the discrete choice experiment (DCE) approach and primary data of tomato consumers from Islamabad.

Findings reveal that consumers not only prefer the reduction in pesticide and fertiliser use and adoption of efficient irrigation technologies, but they also want the inspection of the actual implementation. WTP estimates show that consumers are willing to pay a price premium for the reduction in pesticide and fertiliser use, adoption of efficient irrigation methods, and their inspection. However, consumer WTP for inspection of proposed changes in tomato crop management is higher than other attributes, which is due to the prevalence of food fraud and poor compliance record of the producers. Furthermore, consumers have a higher WTP for greater levels of proposed changes and their inspection. These findings clearly indicate that market-based mechanisms to reduce agricultural pollution and adopt sustainable agriculture might be a viable option in Pakistan.

Key words: *Discrete choice experiment, incentive, willingness to pay (WTP), price premium, health- and environment-friendly.*

6.1 Introduction

The advent of modernization in agriculture heralded a new era of prosperity, lifted masses out of poverty, hunger and food insecurity, in addition to raising the living standards of farmers around the world (Zulfiqar and Thapa, 2017; Lanz et al., 2018; Muhmood et al., 2019). However, this has brought intensive farming to the forefront of agricultural practices (Adnan et al., 2017; Nkomoki et al., 2018), a symptom of which has been a lack of a balance between farmers' private gains and social good from agriculture (Carmona-Torres et al., 2016; Bell et al., 2016). Unfortunately, this has led to adverse consequences for human health (Lai, 2017) as well as for the natural environment (Schutter, 2017; Tambo and Mockshell, 2018), provoking a trade-off between agricultural production and environmental quality (Wood et al., 2016, Sida et al., 2018) due to pollution as a negative externality of agricultural output (Areal et al., 2018).

The concentrated use of agricultural inputs such as water, land, and agrochemicals can be held mainly responsible for this state of affairs, since intensive use of these inputs not only deteriorates human health and ecosystem services (Xu et al., 2018; Wagner et al., 2018; Tamboa and Mockshell, 2018), but also results in a loss of global biodiversity (Lanz et al., 2018; Lafuite et al., 2018). As such, the growing concern of water shortages and their consequences for different industries including agriculture is not a separate issue, but an outcome of the same problem and a piece of the same puzzle (Li et al., 2018). Fortunately, due to the recent increase in consumers' and policy makers' awareness of these issues (Liu and Niyongira, 2017; Sidhoum, 2018), this challenge is being highlighted, contributing to a demand for stern action in ensuring that adequate food safety measures are being taken at various levels (Ha et al., 2018; Omari et al., 2018; Bou-Mitri et al., 2018).

This demand points overwhelmingly to a set of food safety standards, which can only be achieved by adopting health- and environment-friendly sustainable agricultural practices (Trujillo-Barrera et al., 2016; Asioli et al., 2017). Thus, the adoption of sustainable agricultural production practices is immensely important and necessary to reduce the negative impacts of agriculture on human health and the environment and enhance on-farm conservation (Kassie et al., 2015; Zeweld et al., 2017; Krupnik et al., 2017), in addition to giving due consideration to the distress of consumers who are the end users and ultimate beneficiaries. However, the uptake of sustainable agricultural practices has remained low (Bell et al., 2016; Nkomoki et al., 2018; Ward et al., 2018; Daryanto et al., 2019), motivated by the perceived economic benefits of intensive farming, and especially the temptation to pursue short-term private gains that exploit on-farm environmental resources which result in long-term social cost (Petersen and Snapp, 2015; Scherer et al., 2018).

In an attempt to mitigate this problem, policy makers have used regulations to tackle agricultural pollution and achieve the desired environmental outcomes, however these have been proven both insufficient (Sidemo-Holm et al., 2018a) and contentious (Petersen and Snapp, 2015). Instead, economic instruments such as incentive-based mechanisms are increasingly being proposed as a way to restrict agricultural pollution (Petersen and Snapp, 2015; Sidemo-Holm et al., 2018). Incentive-based mechanisms are devised on the basis of economic efficiency, i.e. achieving maximum resource protection for a given level of production (Lafuite et al., 2018), and are considered more efficient than regulations (Van Hecken et al., 2019). These mechanisms help in designing compensations for farmers to modify their farming practices (Capmourteres et al., 2018), which make the proposed changes attractive for them to undertake (Ezzine-de-Blas et al., 2019). This is a way of cost-sharing that compensates farmers for adopting the proposed practices and management options (Fleming, 2017; Banerjee and Conte, 2018).

This study also proposes to use market-based mechanisms to curb agricultural pollution and subsequent problems in tomato cultivation in Khushab District of Pakistan. Agriculture in Pakistan is mostly unsustainable (Zulfiqar and Thapa, 2017) where farmers are heavily reliant on intensive farming approaches which involve the concentrated use of agricultural inputs, including agrochemicals, which are damaging to human health and the environment (Abedullah et al., 2015; Murtaza et al., 2015). This is mainly due to farmers' asymmetric dependence on agriculture in terms of food, fodder, and livelihood (Elahi et al., 2018), which forces them to adopt the means to enhance crop yields, even if such means are unsustainable.

Nevertheless, the uncontrolled use of agrochemicals in intensive farming is a serious threat to human health in Pakistan. For example, pesticide residue has been found in the blood samples of people in the Vehari District of Pakistan (Saeed et al., 2017). Research has also indicated that there is evidence of the presence of pesticide and fertiliser residue in Pakistan's water supply (Tariq et al., 2007; Azizullah et al., 2011; Waseem et al., 2014). The overuse of agrochemicals in Pakistan (Tariq et al., 2007) is because of farming communities' lack of awareness of agrochemicals' harmful effects (Azizullah et al., 2011), poor agrochemical administration training, limited knowledge of recommended dosages (Saeed et al., 2017), and thin environmental compliance (Tariq et al., 2007). These have caused massive damage to human health, as research reveals the shocking statistics that more than 500,000 Pakistanis suffered agrochemicals poisoning annually, of which 10,000 proved fatal (Shahid et al., 2016).

Therefore, there is clearly an urgent need to address this pervasive problem to avoid further damage to human health and the natural environment, while also mitigating the subsequent economic cost. As stated earlier, market-based mechanisms could be used to address this problem as market-based mechanisms could encourage farmers to adopt the desired health- and environment-friendly agricultural production methods (Ward et al., 2018; Areal et al., 2018). In this pursuit, the present research investigates consumers' preferences to modify the current agricultural practices used in tomato cultivation in Khushab, Pakistan. The proposed changes include reduction in the use of agrochemicals (pesticides and fertilisers) and adoption of efficient irrigation methods (furrow and drip). Since consumers are the end users of tomatoes produced with the intensive use of agrochemicals which has health implications, it is important to investigate their preferences for the proposed changes. Furthermore, consumers might also prefer that the food they consume should be grown using efficient irrigation methods which conserve the irrigation water.

As such, this study also proposes to use the economic incentive schemes, which are used as an innovative market-based policy tool (Galik and Olander, 2018) to achieve this end, in a regulation-driven environment. The idea of economic incentive schemes in this study is based on the "Provider Gets Principle", proposed by Hanley et al. (1998). "Provider Gets Principle" says that farmers are compensated for activities that help avoid the harm to or enhance environmental amenities. The farmer compensation in the present research is the price premium on cleaner tomatoes that is paid by consumers against farmers' implementation of the proposed changes.

Using discrete choice experiment (DCE) and primary data, the present research seeks to understand consumer preferences to reduce pesticide and fertiliser use and adopt water efficient irrigation technologies in the tomato crop in Khushab Pakistan. Since the tomatoes grown in Khushab are supplied in different markets including Islamabad, the capital of Pakistan, the survey for this research was administered to tomato consumers in Islamabad. The analysis reveals the consumer willingness to pay (WTP) to implement the proposed changes, which could be used to set the price premium for the production and supply of cleaner tomatoes. This can open up an avenue towards the novel use and understanding of market-based approaches, i.e. economic incentive schemes, to design food and agricultural policies in Pakistan. Such incentive schemes can help attain the judicious use of agricultural inputs, enhance environmental compliance, and ensure cleaner food production.

This study aims to investigate the following specific research questions:

6.1.1 Research questions

1. What are consumer preferences to reduce pesticide and fertiliser use and adopt water efficient irrigation technologies?
2. What are consumer WTP for the proposed changes in current agricultural practices used in tomato crop production?

3. How could findings of this research inform policy makers in the design of market-based mechanisms to modify the existing agricultural practices?

The layout of this chapter is as follows: section 6.2 presents the literature review, section 6.3 describes the material and methods of this research, section 6.4 discusses the results, and section 6.5 presents the conclusion and policy implications.

6.2 Literature review

This section discusses relevant DCE studies on consumers' preferences for sustainable agricultural practices such as health- and environment-friendly agriculture and cleaner food production. Literature shows that generally consumers derive disutility from the use of agrochemicals for their impacts on human health and the environment. For example, Chalak et al.'s (2008) investigated consumers' preferences for pesticide reduction for environmental quality and consumer health and found that consumers place a high value on reduction of pesticides' use. A similar study by Travisia and Nijkamp (2008) evaluated pesticides' health and environmental risks and reported that respondents are willing to pay a price premium for food produced in environmentally-friendly ways. Zheng et al. (2022) study shows that consumers are more willing to pay for pesticide-free labels.

Similarly, Li et al. (2022) report that consumers are willing to pay a certain fee to control agricultural non-point-source pollution. In this regard, Savchenko et al. (2018) reported that consumers derive disutility from recycled water use in food crop irrigation and have lower WTP for the produce irrigated with recycled water. However, consumers also dislike environmental externalities associated with agriculture. For example, Novikova et al.'s (2017) study on agro-ecosystem services shows that individuals are concerned about the environmental consequences of agriculture and demand improvements in agro-ecosystem services. Research by Crastes et al. (2014) assessed the value of mitigating erosive runoff events and reported significant preference heterogeneity in respondents' preferences and WTP, though each management alternative has substantial benefits. Likewise, Chaikaew et al. (2017) studies citizens' preferences for provision and regulation of ecosystem services and shows that respondents consider water quality as the most important service.

Research shows consumers have a preference for the adoption of sustainable agriculture as it mitigates the negative agricultural externalities. For example, Bronnmann and Asche (2017) study on seafood sustainability revealed that consumers have higher WTP for seafood certified to be sustainable using an ecolabel, which indicates their environmental concerns. Aprile and Punzo (2022) claim that consumers' demonstrate greater inclinations towards environmental sustainability labelled product and hence WTP if they have understanding of the benefits of sustainability labels. Likewise, Yue et al. (2020) reported that consumers value sustainable certification in addition to demonstrating a consistent preference for farmers' engagements in sustainable practices.

Consumers' food choices are also influenced by the information. For example, Cerroni et al.'s (2018) research reported that information regarding food safety affects consumers' preferences as well as welfare measures. Similarly, Balcombe et al. (2015) explored the role of customized information provision in food choice and reported that consumers prefer specific information as opposed to the generic nutritional information provided on food labels and are willing to pay more for specific information. Savchenko et al. (2018) show that information about the risks of recycled water irrigation reduces consumer WTP by 50%, although information about its environmental benefits has insignificant impact.

Most of the prior research however has examined food production attributes which have private benefits for consumers, however, the present research investigates private as well as social aspects of food production as consumers evaluated irrigation water in addition to agrochemical use reduction. Furthermore, this study also includes inspection of the proposed changes as a credence attribute, which uncovers the value consumers place on farmer compliance with the proposed changes.

The next section outlines the methodology used to conduct this research.

6.3 Material and methods

The material and methods used in this analysis are presented and discussed in Chapter 2 and 3.

6.4 Results discussion

6.4.1 Consumer sample characteristics

The consumer survey was administered to the vegetable consumers in Islamabad city. While the average age of respondents is 36 years; average years of their formal education are 15 (Table 6.1), which means that the sample largely comprises young people who are educated. This is expected as the study site is an urban setting with relatively higher socioeconomic standard of the residents. Data were also collected on the maximum years of education (i.e. the years of education of the person with most education in the household, be it the head of the household or not) in a household due to its possible influence on households' decision-making and the mean of the maximum years of education for consumer households is 17 years. There is a significant fraction of households where the maximum years of education in a household are higher than the education of the household head, as witnessed in the farmers' survey.

Data shows that the average of the household monthly income is 152,496 Pakistani rupees (USD 958.336 at 12/07/2019), while the minimum reported monthly income is 20,000 Pakistani rupees (USD 125.687 at 12/07/2019). This indicates that the sample is drawn from diverse income groups. The monthly average household income in this sample is higher than that of Urban Punjab (45,283 PKRs) (that includes Islamabad), reported in the Pakistan Household Integrated Economic Survey (HIES) 2015-16. This is because the study sample comprises relatively affluent respondents, as indicated above.

Table 6.1: Consumers' socioeconomic characteristics

Characteristics	Mean	St. Dev.	Min.	Max.
Age (years)	36.601	10.742	18	72
Education (years of schooling)	15. 754	2.311	8	22
Max. education (years of schooling)	17.082	1.982	10	22
Household income (PKRs)	152,496	123,821	20,000	1,500,000
Gender	0.313	0.462	0	1
Household size	6.339	3.094	2	35
Tomato consumption (kgs)	2.871	1.602	0	10
Children	1.556	1.527	0	6
Awareness[11]	0.495	0.5	0	1

Approximately 69% respondents in this survey are women, as it is an urban setting and women prefer to do the shopping while male members of the household work outside. Furthermore, in Pakistani culture, women are often in charge of household chores, especially cooking. The average household size of the sample is six, which is in line with the Population Census 2017 data of Urban Islamabad. The weekly average tomato consumption of households in the sample is approximately three kilograms.s

6.4.2 DCE estimates

Discrete choice models are estimated to investigate consumer preferences for sustainable agricultural practices and results presented in this section are obtained from mixed logit models estimated in preference-space and price-space.

a. Uncorrelated coefficients in preference space

A mixed logit model is specified in preference-space with random coefficients and no correlation across coefficients (Table 6.2). This model does not allow for random scale, as it is not possible to separate scale heterogeneity from correlation in preference heterogeneity (Hess & Train 2017). A model with fully correlated coefficients is presented later. The coefficient for price premium is fixed (i.e. it is a point estimate, as in a non-random coefficient) and the remaining coefficients are specified to be normally distributed. While assuming the constant marginal utility of money is unrealistic, the reason for using a fixed price is to be able to obtain the finite moments of consumer WTP. An

[11] Consumer awareness of the amounts of agrochemicals used in tomato crop production.

alternative way to bypass this problem is to estimate the model directly in price-space, as advised by Daly et al. (2012). Such a model is presented and discussed later in this section.

The model is estimated with 1000 Halton draws and the results include means and standard deviations of the coefficient distributions, except for the price which is fixed. The estimates are obtained using a simulated maximum likelihood approach. Generally, the DCE attributes are either desirable or undesirable, depending on the views and tastes of the respondents. However, since consumers prefer the proposed changes to produce cleaner food, they place a positive value on attributes representing the stated changes in tomato cultivation. Coefficients of the attributes reflect the value of the proposed changes in agricultural practices used for tomato cultivation relative to the status-quo.

Table 6.2: Model in preference-space with uncorrelated coefficients

Base model			
Attribute	*Parameter*	*Estimate*	*St. Error*
Status-quo	Mean of coeff.	-1.934	0.358
	St. dev. of coeff.	2.354	0.272
Furrow irrigation	Mean of coeff.	0.406	0.125
	St. dev. of coeff.	0.313	0.287
Drip irrigation	Mean of coeff.	0.688	0.138
	St. dev. of coeff.	0.614	0.180
33% less fertilisers	Mean of coeff.	0.533	0.107
	St. dev. of coeff.	0.001	0.176
50% less fertilisers	Mean of coeff.	0.635	0.104
	St. dev. of coeff.	0.045	0.464
25% less pesticides	Mean of coeff.	0.231	0.107
	St. dev. of coeff.	0.032	0.342
33% less pesticides	Mean of coeff.	0.341	0.111
	St. dev. of coeff.	0.012	0.283
2 times inspection	Mean of coeff.	0.823	0.122
	St. dev. of coeff.	0.513	0.256
4 times inspection	Mean of coeff.	0.894	0.119
	St. dev. of coeff.	0.833	0.166
Price premium	Mean of coeff.	-0.050	0.006
Log likelihood	-1249.22	-	-
No. of parameters	20	-	-
Observation	4,482	-	-
N	249	-	-

The attributes used in consumer surveys are status-quo, irrigation (furrow and drip), fertiliser reductions (33% and 50%), pesticide reductions (25% and 33%), and inspection (two and four times). The coefficient (alternative specific constant) for the status-quo variable shows consumer (dis)utility from the existing agricultural practices. The coefficient for the furrow irrigation captures the utility associated with the furrow irrigation method relative to the flood irrigation, and the coefficient for the drip irrigation reflects the value of drip irrigation technology relative to the furrow irrigation. The coefficients of the first variables of fertiliser and pesticide reductions capture the utility associated with smaller reductions, while the coefficients of the second levels of the fertiliser and pesticide reductions reflect the utility associated with greater reductions. Similarly, the coefficient for the first variable of inspection reflects the value of two times inspection relative to no inspection, while the coefficient for the second inspection variable reflects the utility associated with four times inspection relative to the two times.

Table 6.3: Model in preference-space with uncorrelated coefficients & interactions

Model with attribute interactions			
Attribute	*Parameter*	*Estimate*	*St. Error*
Status-quo	Mean of coeff.	-1.899	0.353
	St. dev. of coeff.	2.260	0.267
Furrow irrigation	Mean of coeff.	0.297	0.140
	St. dev. of coeff.	0.335	0.276
Drip irrigation	Mean of coeff.	0.691	0.140
	St. dev. of coeff.	0.629	0.181
33% less fertilisers	Mean of coeff.	0.533	0.108
	St. dev. of coeff.	0.001	0.176
50% less fertilisers	Mean of coeff.	0.393	0.131
	St. dev. of coeff.	0.018	0.353
25% less pesticides	Mean of coeff.	0.235	0.108
	St. dev. of coeff.	0.032	0.336
33% less pesticides	Mean of coeff.	0.331	0.112
	St. dev. of coeff.	0.009	0.275
2 times inspection	Mean of coeff.	0.823	0.123
	St. dev. of coeff.	0.549	0.251
4 times inspection	Mean of coeff.	0.644	0.160
	St. dev. of coeff.	0.861	0.167
Price premium	Mean of coeff.	-0.051	0.006
	St. dev. of coeff.	-	-
50% less fertiliser×children	Mean of coeff.	0.154	0.054
	St. dev. of coeff.	-	-
4 times inspection×children	Mean of coeff.	0.166	0.071
	St. dev. of coeff.	-	-
Furrow irrigation×gender	Mean of coeff.	0.367	0.187
	St. dev. of coeff.	-	-
Log likelihood	-1240.359	-	-
No. of parameters	23	-	-
Observation	4,482	-	-
N	249	-	-

Table 6.2 results for a mixed logit model in preference-space with uncorrelated coefficients. Model estimates are generally reasonable as all the attribute coefficients are significant with expected signs. All else equal, the status-quo is considered worse than the proposed changes by the majority of the population which shows that consumers dislike existing agricultural practices used in tomato cultivation when compared with the alternatives offered in the choice tasks. The mean and standard

deviation of the status-quo coefficient show that almost 79% percent of the population place a negative value on status-quo relative to the proposed changes. Consumers value the improvement in the irrigation efficiency as the use of drip irrigation technology is preferred to furrow irrigation, while furrow irrigation is considered better than the flood irrigation.

A model similar to the one reported in Table 6.3, but allowing for correlation between all random coefficients (i.e. all coefficients but price's) was also estimated. This model reached a log likelihood of 1224.16, while using 55 parameters. Details of the model can be seen in Appendix E (E4-5). A likelihood ratio test indicates that there is no significant difference between the fit of the two (likelihood ratio is 50.1, while critical table value is 51.0 at 95% confidence). Therefore, all future models are estimated assuming independence of random coefficients.

Consumers prefer reduced use of fertilisers and pesticides (proposed reductions) to their current use in tomato crop. The coefficients of both fertiliser variables capture the utility associated with the decrease in fertilisers by 33% and 50% of their current use, while the coefficients of both pesticide variables reflect the extra utility associated with 25% and 33% lower use of pesticides. Similarly, inspection of the proposed changes is preferred over no inspection. The coefficient for the first inspection variable shows the value associated with the two-times inspection per crop season, whereas the coefficient for the second inspection variable reflects the utility consumers derive from four-times inspection per crop season. As expected, these results show that consumers prefer the attributes of cleaner tomato production which is in line with previous research e.g. Travisia and Nijkamp, (2008); De Marchi et al. (2016), Apostolidis et al. (2016), Tait et al. (2016), Balcombe et al. (2016), Bronnmann and Asche, (2017), Printezis and Grebitus, (2018) and Risius et al. (2019).

The standard deviations of the fertiliser and pesticide reduction variables are much lower than those of the status-quo, irrigation and inspection coefficients. This indicates that consumers are more similar in their desire for reduction in the use of fertilisers and pesticides than in their value for status-quo, irrigation and inspection. It is interesting to see that the proposed changes are valued at an increasing rate. For example, the average utility associated with moving from furrow irrigation to drip irrigation technology is greater than that for moving from status-quo (flood irrigation) to furrow irrigation (0.688 and 0.406 respectively). Similarly, the average utilities associated with the larger amounts of fertiliser and pesticide reductions (0.635 and 0.341 respectively) are greater than those for the smaller amounts (0.533 and 0.231 respectively).

Overall, findings imply that, given the option of alternative production methods, consumers place a negative value on intensive farming as currently practiced in tomato cultivation in study areas, and they prefer modification in existing agricultural practices. Similar findings have been reported in other studies on consumer preferences for health- and environment-friendly farming practices (e.g. Ragkos and Theodoridis, 2016; Crastes et al., 2016; Novikova et al., 2016; Chaikaew et al., 2017; Lee and Wang et al., 2017).

Model in preference-space with uncorrelated coefficients is also estimated with few attribute interactions found to be significant and meaningful to explore the observed interpersonal heterogeneity in consumer preferences (Table 6.3). The specification search process followed a "backward" strategy. Commencing from a model with all potentially relevant interactions between alternative attributes and respondents characteristics, the least significant parameter is removed, and the model is estimated again, until only significant or policy relevant coefficients remain. Main effects are preserved in the model, even if they do not reach 95% significance. The initial model is presented in Appendix – F.

Attribute interaction terms have fixed coefficients and were created using the average value of the socio-demographic factors, e.g. children. While there are other ways (e.g. allowing scale heterogeneity) to investigate observed interpersonal heterogeneity in respondent choices as well, this research uses the attribute interactions as this method is more suitable to generate context specific information, and hence give policy suggestions which is the main objective of this research.

As the inclusion of attribute interactions does not alter the value of coefficients without interactions, the discussion is restricted to interactions only. The interactions of the second variable of fertiliser reductions and four times inspection per crop season with children in a household are significant. This shows that consumers with children prefer greater fertiliser reductions and stringent inspection of proposed changes relative to those who have no children, indicating that household composition influences consumer choices and thereby explains the heterogeneity in their preferences. These findings are in line with Savchenko et al.'s (2018) study, which shows that the households with the presence of a child are less likely to purchase food irrigated with recycled water. Similarly, the interaction of furrow irrigation with gender variables shows that men prefer furrow irrigation more than women, which means that drip irrigation technology is valued more, on average, than the furrow irrigation by the women in the study sample. The most plausible interpretation of these results is that since women deal with household chores in Pakistan, they are more aware of the water shortages their households face, and hence prefer more water efficient irrigation technology.

Table 6.4 shows the WTP distributions derived from the model in preference-space, including the estimated mean and standard deviation of the WTP for each attribute. Again, WTP estimates are presented both for the sample and the population, and the values for the sample are calculated based on the individual level parameters. First, individual level parameters are calculated for each individual in the sample following the procedure described by Train (2009) Chapter 11. Then, the mean and standard deviation are calculated from the list of values, while the standard error of the mean is calculated using the corresponding STATA willingness to pay command, given in the STATA code appendix. In the case of the population WTP values, these are calculated simply by dividing the mean and standard deviations reported in Tables 6.3 and 6.4 by the price coefficient.

Table 6.4: WTP from models in preference-space with uncorrelated coefficients

Base model								
	Sample				Population			
Attribute	Mean		St. Dev.*		Mean		St. Dev.	
Furrow irrigation	8.11	(2.88)	1.73		8.12	(2.50)	6.26	(5.74)
Drip irrigation	13.74	(3.47)	5.44		13.76	(2.76)	12.28	(3.60)
33% less fertilisers	10.64	(2.51)	0.01		10.66	(2.14)	0.02	(3.52)
50% less fertilisers	12.67	(2.55)	0.22		12.70	(2.08)	0.90	(9.28)
25% less pesticides	4.61	(2.29)	0.15		4.62	(2.14)	0.64	(6.84)
33% less pesticides	6.80	(2.46)	0.05		6.82	(2.22)	0.24	(5.66)
2 times inspection	16.41	(2.89)	4.36		16.46	(2.44)	10.26	(5.12)
4 times inspection	17.84	(2.96)	8.94		17.88	(2.38)	16.66	(3.32)
Model with attribute interactions								
	Sample				Population			
	Mean		St. Dev.*		Mean		St. Dev.	
Furrow irrigation	5.81	(2.97)	1.88		5.82	(2.75)	6.57	(5.41)
Drip irrigation	13.52	(3.42)	5.54		13.55	(2.75)	12.33	(3.55)
33% less fertilisers	10.43	(2.48)	0.00		10.45	(2.12)	0.02	(3.45)
50% less fertilisers	7.68	(2.77)	0.09		7.71	(2.57)	0.35	(6.92)
25% less pesticides	4.61	(2.27)	0.16		4.61	(2.12)	0.63	(6.59)
33% less pesticides	6.48	(2.43)	0.04		6.49	(2.20)	0.18	(5.39)
2 times inspection	16.12	(2.86)	4.87		16.14	(2.41)	10.76	(4.92)
4 times inspection	12.59	(3.39)	9.22		12.63	(3.14)	16.88	(3.27)
50% less fertiliser×children	12.37	(2.51)			3.02	(1.06)		
4 times inspection×children	17.64	(2.93)			3.25	(1.39)		
Furrow irrigation×gender	8.01	(2.85)			7.20	(3.67)		
** st.dev. of sample WTA does not have s.e., as it is calculated from point estimates for each individual*								

For preference-space models, a convenient distribution is specified for the coefficients and WTP is derived from the estimated distribution of coefficients. In this case, as the coefficients follow normal distributions, except for the price premium coefficient that is a point estimate, all WTP measures also follow normal distributions. The estimated distributions of WTP show that irrigation and inspection variables have significant standard deviations, which means that a significant fraction of survey participants is willing to pay greater amounts of money for improvement in irrigation and inspection of the proposed changes in current agricultural practices used in tomato crop. Interestingly, as noted for utility coefficients, consumer WTP estimates also demonstrate the increasing rate, for example, consumer WTP for drip irrigation technology is considerably greater than their WTP for furrow irrigation. Similarly, consumer WTP's are higher for greater levels of fertiliser and pesticide reductions, and WTP for four-times inspection is also higher than the two-times inspection. Amongst all attributes, consumer WTP's are highest for the inspection variables.

The percentile distribution of consumer WTP's is derived using the individual-level estimates of the model, i.e. these are the sample quantiles. The percentiles of the WTP distribution calculated with the individual level and the population coefficients are similar, exhibiting the same trends. They differ more the further away from the median they are. This is to be expected as the individual level parameters do not cover the tail of the distribution of the population parameters very thoroughly, instead concentrating themselves closer to the median. This leads to attributes such as drip irrigation and "4 times inspection" having a negative WTP for the 10th percentile. It is likely these negative values are more a consequence of the tails of the normal distribution, more than a true behavioural trait of the respondents.

WTP estimate results are in line with the Chalak et al.'s (2008) study that reports reasonably high WTP estimates for reduction in the use of pesticides for both environmental quality and consumer health. As consumer households with children are estimated to have additional WTP's for greater fertiliser reductions and four-time inspection, Niedermayr et al.'s (2018) study also found the positive impact of children on consumer WTP. WTP estimates for fertiliser and pesticide use reductions are also in-line with Ragkos and Theodoridis,' (2016) and Tait et al.'s (2019) studies which show consumer positive WTP for reduction in agrochemicals use. It is important to highlight that the WTP's calculated using Stata code and those from individual-level parameters are the same. Furthermore, the percentile distribution of WTP's for the proposed changes presented in Table 6.6 is also calculated from the individual-level estimates.

Table 6.5: Percentiles of WTP distribution from individual level coefficients

Attributes	10th	20th	25th	50th	75th	80th	90th
Furrow irrigation	6.115	6.736	6.893	8.071	9.142	9.360	10.220
Drip irrigation	6.587	9.166	10.062	12.671	17.359	18.377	20.752
33% less fertilisers	10.634	10.637	10.637	10.639	10.642	10.642	10.645
50% less fertilisers	12.422	12.530	12.552	12.668	12.785	12.817	12.909
25% less pesticides	4.460	4.512	4.536	4.617	4.699	4.719	4.770
33% less pesticides	6.736	6.762	6.769	6.802	6.836	6.843	6.870
2 times inspection	10.702	12.610	13.606	16.524	19.022	19.935	21.265
4 times inspection	6.347	10.280	11.625	17.755	23.503	25.174	30.509

The percentile distribution of WTP shows that WTP's for the proposed changes in current agricultural practices are positive. WTP's for irrigation and inspection variables demonstrate a gradual and consistent increase, however, WTP's for fertiliser and pesticide variables are almost same for all percentiles, i.e. there is a negligible increase. Considering the market price[12] of tomatoes per kilogram, consumer WTP's for the proposed changes seem generally high as the WTP for each attribute of the proposed change is the additional amount (price premium) a consumer will have to pay for each kilogram of the cleaner tomatoes. While there is variation across the attributes, roughly more than 50% of the surveyed consumers are willing to pay a price premium for cleaner tomatoes which is a significant fraction of the tomato price per kilogram.

Table 6.6: Percentiles of WTP distribution from population level coefficients

Attributes	10^{th}	20^{th}	25^{th}	50^{th}	75^{th}	80^{th}	90th
Furrow irrigation	0.097	2.851	3.898	8.120	12.342	13.389	16.143
Drip irrigation	-1.977	3.425	5.477	13.760	22.043	24.095	29.497
33% less fertilisers	10.634	10.643	10.647	10.660	10.673	10.677	10.686
50% less fertilisers	11.547	11.943	12.093	12.700	13.307	13.457	13.853
25% less pesticides	3.800	4.081	4.188	4.620	5.052	5.159	5.440
33% less pesticides	6.512	6.618	6.658	6.820	6.982	7.022	7.128
2 times inspection	3.311	7.825	9.540	16.460	23.380	25.095	29.609
4 times inspection	-3.471	3.859	6.643	17.880	29.117	31.901	39.231

The above presented results provide an answer to the fourth research question of the present research (stated in Chapter 1) which investigates the consumer preferences and their WTP to reduce pesticide and fertiliser use and adopt efficient irrigation technologies in the tomato crop in Khushab.

While mixed logit is a commonly used model specification in discrete choice analysis, there are some practical problems associated with its estimation which remain unsolved (Sillano and Ortuzar, 2005). For example, there is a debate on the validity of implied WTP estimates from mixed logit models estimated in preference space. Since the cost or price coefficient enters the denominator of the WTP, its distribution determines the distribution of WTP. As Daly et al. (2012) elaborated in their paper, this may be correct in the theory, but it can be problematic in practice as a value of the cost coefficient that is close to zero can result in very large WTP. Furthermore, there might be a problem of lack of moments of the WTP distribution for a given distribution of the cost coefficient which undermines the value of results from a policy appraisal point of view.

According to Daly et al. (2012), many commonly used distributions for the cost coefficient imply that the distribution of WTP has undefined or infinite moments. Authors claim that the simulation method to deal with the problem of lack of moments of WTP, used by some researchers, only masks the problem, and provides incorrect finite moments. In this regard, Sillano and Ortuzar (2005) argue that estimating individual-level parameters is a useful procedure to circumvent the problem which the present research has attempted. Daly et al. (2012) however think that the most straightforward

[12] Tomato price remains very volatile due to fluctuation in the supply and demand and seasonal changes. On average, one kilogram tomato price is between 40 rupees to 80 rupees.

solution to this problem is to estimate the model in WTP- or price-space. Therefore, the present research has adopted the estimation in price-space where the distribution of WTP is estimated directly rather than deriving from the estimated coefficient distributions.

b. Uncorrelated WTP in price-space

The model is estimated in price-space in such a way that the coefficient of each non-price attribute is the product of the WTP for that attribute multiplied by the price coefficient. All variables are specified to be normal, except for the price premium which is log-normal. This model allows for random scale, and the assumption is that the WTP's are uncorrelated over attributes. Uncorrelated WTP estimates imply correlated coefficients which are due to the common influence of the price coefficient on each other coefficient. Table 6.7 presents the results of the model estimated in rice-space. The log-likelihood of the model in price-space is lower than the model in preference-space, which is in contrast to the farmer survey results presented in Chapter 5. This implies that model in preference-space has a better model fit than the model in price-space which is similar to the results reported by Train and Weeks (2005), Sonnier et al. (2007), Hole and Kolstad, (2012) and Coffie et al. (2016), while Scarpa et al. (2008) find that the price-space model fits their data better.

Table 6.7: Model in price-space with uncorrelated WTP's

Attribute	*Parameter*	*Estimate*	*St. error*
Status-quo	Mean of coeff.	-40.254	7.570
	St. dev. of coeff.	46.303	8.045
Furrow irrigation	Mean of coeff.	7.792	2.796
	St. dev. of coeff.	6.056	5.107
Drip irrigation	Mean of coeff.	13.046	3.377
	St. dev. of coeff.	12.332	3.277
33% less fertilisers	Mean of coeff.	9.864	2.468
	St. dev. of coeff.	0.141	3.168
50% less fertilisers	Mean of coeff.	11.833	2.490
	St. dev. of coeff.	1.994	8.367
25% less pesticides	Mean of coeff.	4.318	2.211
	St. dev. of coeff.	0.014	4.886
33% less pesticides	Mean of coeff.	6.489	2.407
	St. dev. of coeff.	0.248	4.964
2 times inspection	Mean of coeff.	15.752	2.734
	St. dev. of coeff.	8.272	5.593
4 times inspection	Mean of coeff.	17.350	2.892
	St. dev. of coeff.	16.130	3.265
Scale	Mean of coeff.	2.942	0.126
	St. dev. of coeff.	0.435	0.179
Log likelihood	-1242.919	-	-
No. of parameters	20	-	-
Observation	4,482	-	-
N	249	-	-

The model in price-space shows that the means of the coefficients have the expected signs. Moreover, the estimates are consistent in terms of signs and significance across preference-space and price-space. However, the WTP's from the model in the price-space are not significantly different from the implied distribution of WTP's from model in the preference space. For example, the WTP's for both fertiliser variables, furrow irrigation and two times inspection are slightly higher from the model in preference space. Furthermore, unlike Train and Weeks (2005), some of the variables, e.g. inspection and irrigation, have significant standard deviations for WTP's from the model in price-space.

This indicates that there is a significant fraction of respondents with large WTP's for inspection and irrigation attributes which reflects preference heterogeneity in consumer choices. Nevertheless, Hole and Kolstad (2012) also report high standard deviations of WTP measures from their model in price-space. Implied ranking of the means of the WTP distributions from model in preference-space and model in price-space remain same, as reported by Hole and Kolstad (2012). Hence, unlike previous studies, e.g. Train and Weeks (2005), Sonnier et al. (2007), Hole and Kolstad (2012), WTP distributions are not very different even when the distributions are estimated directly rather than an indirect way of estimating the distributions.

As mixed logit model specification allows for unobserved interpersonal heterogeneity, models in preference- and price-space reveal significant unobserved variation (across individuals) in some of the attributes as the standard deviations of the random terms are significantly different from zero. This shows that there is a high dispersion in the utility of proposed changes and (dis)utility of price premium due to unobserved tastes.

c. Results discussion

Since this is an applied research and its aim is to generate policy suggestions to adopt the sustainable agricultural practices, it is important to put the findings in the context and discuss their meanings in more detail. Results of this research have contributed to a deeper understanding of consumer preferences and their WTP to implement the proposed changes in current agricultural practices used in tomato crop. This includes the discovery and quantification of the trade-offs consumers make regarding different attributes of cleaner tomatoes. For example, consumer dissatisfaction with current agricultural practices compared to alternatives presented in the survey shows that given the option of alternative production methods, consumers place a negative value on intensive farming as is used in tomato cultivation in Khushab Pakistan. Consumers' keen interest in cleaner tomato attributes suggest that they are willing to buy relatively cleaner tomatoes against a price premium.

Findings uncover that households with children are more likely to purchase cleaner tomatoes and pay a price premium. Most plausible interpretation of this is that households with children perceive a potential risk to children's health due to unsafe food consumption and subsequent illness as this could lead to an unexpected health cost, which has implications for overall financial stability of the household. Findings also show that consumers place a relatively high value on inspection of the actual implementation of proposed changes in tomato crop production. Consumers' preference for stringent inspection indicates that they perceive serious inadequacies in Pakistani food monitoring systems, resulting in significantly low consumer confidence. This points towards the poor food quality standards and thin environmental compliance in food production and supply. Studies on consumer WTP for food labelling (e.g. Hoefkens et al., 2012; Wang et al., 2018; Tait et al., 2019) yield similar insights.

It is remarkable to note that consumer WTP for the attributes of cleaner tomatoes is higher than the farmer WTA (presented in Chapter 5) to implement the proposed changes in current agricultural practices used in tomato cultivation. This shows that market can offer adequate compensations to farmers to implement the proposed changes in tomato crop, which can help in creating a market-based system that incentivises cleaner tomato production. This means that the use of market-based mechanisms for the adoption of sustainable agricultural practices in tomato cultivation in study areas is economically viable. Findings of this research also offer actionable information for food businesses that seek to exploit the market niches of cleaner food production and supply. From a policy design point of view, there is a need to facilitate the production and sale of cleaner tomatoes which could be achieved by improving the supply chain, and putting in place a trustworthy and reliable food inspection and labelling system. This would be instrumental in developing a market-based mechanism for cleaner food production and helping farmers to market their produce.

6.5 Conclusion and policy implications

Studying consumer preferences for sustainable agricultural practices is immensely important in the context of the present research, not only because it is necessary to investigate the demand side of cleaner tomato production, but also to understand the economic viability of this research's central idea: the use of market-based mechanisms for the adoption of sustainable agricultural practices in Pakistan. It is in this context, therefore, that the analysis seeks to develop an understanding of the factors, including socio-demographic characteristics, which determine consumer *choices* and their valuation of sustainable agricultural practices for cleaner tomato production.

While the farmer survey discovered interesting social phenomena that drive farmer preferences (land tenancy) in a rural tribal setting, consumer data analysis makes a compelling case for the composition of a household fulfilling a similar causal function, e.g. the presence of children in a household and its preference to consume relatively cleaner tomatoes. These insights, therefore, render a clear understanding of consumer preferences for cleaner food in an urban context, and enabled the discovery of their *underlying causes*; thus, generating an interesting set of policy suggestions regarding the use of market-based approaches. For example, utilising the socio-demographic insights might assist the policy makers in designing more *targeted* (and hence cost-effective) interventions. The main findings of this research, which draw meaningful conclusions regarding the application of the DCE approach as well as the key implications for policy makers, are summarized in the remaining part of this section.

Similar to the farmer survey results, the models estimated in preference-space and price-space yield comparable results, and show the prevalence of preference heterogeneity in some of the attributes. However, unlike farmer data, model in preference-space has a better model fit than model in price-space, indicating its suitability for the consumer data. The DCE, as a methodology, was also proven useful in this context as it has contributed to a deeper understanding of consumer preferences, and hence the underlying pattern of their monetary valuation. This enabled the discovery and quantification of the trade-offs consumers make regarding the attributes of cleaner tomatoes. Furthermore, key socio-demographic covariates incorporated to derive consumer utility and their WTP estimates for selected attributes helped in disentangling their impact and providing the context-specific information for policy makers to design the policies. This uncovers the success of the DCEs to investigate the use of market-based approaches for the modification of existing agricultural practices.

Findings reveal that consumers place a negative value on existing agricultural practices and demonstrate their preference for the proposed changes presented to them in the DCEs. Consumer preferences, and the relatively higher valuation for irrigation water conservation reveals that they hold a social value of the environment. This is in contrast to farmers who are unwilling to invest in drip irrigation due to its social and environmental benefits at private cost. However, consumers do not stand to benefit personally from the improvement in irrigation efficiency. This implies that consumers retain a bequest or option value for future resources, thus indicating their intergenerational equity concerns. This could also be due to consumers' relatively higher educational status as this allows them to think of the water scarcity issues in the country and need for water conservation in different sectors, including agriculture. Since, therefore, irrigation water conservation has a significant contribution to citizens' social wellbeing, it gives a strong justification to policy makers for the allocation of resources to improve irrigation efficiency in Pakistani agriculture.

These findings provide an answer to the first research question, regarding consumer preferences to reduce pesticide and fertiliser use and adoption of water efficient irrigation technologies, posed in the introduction section of this chapter.

While consumers place a positive and significant value on all the attributes of the proposed changes, the differences in WTP for each attribute of cleaner tomato production are interesting and warrant a detailed and circumstantial interpretation as consumer WTP's clearly translates their concerns as well as perceived risks. For example, the highest consumer WTP for a single attribute is for inspection; however, this attribute does not exactly signify the proposed changes in current agricultural practices, but rather an assurance of their implementation. Consumers desire some level of serious effort for inspection and place a higher value on it as a feature of tomato crop production. This result, therefore, highlights that consumers perceive serious inadequacies in food quality monitoring, and hence have a lower confidence on food systems in Pakistan in general as compliance with food quality standards is a serious issue in Pakistan. The estimated consumer WTP for irrigation and inspection variables have significant standard deviations, indicating that a fraction of consumers is willing to pay large amounts of money for the improvement in irrigation efficiency and to have the inspection of the proposed changes in existing agricultural practices. This reflects preference heterogeneity in consumer choices, which could be due to the use of normal distributions for the random coefficients, yet it still points out to wide heterogeneity in preferences.

An intriguing result regarding the influence of household composition is the impact of having children on respondents' preferences, as the consumer WTP for greater fertiliser reductions and four time inspection per crop season has a positive correlation with the presence of children in a household. While this indicates parental concerns about the quality of food their children consume, a more compelling interpretation is that it is due to the risk of illness and the subsequent unexpected cost, exposing an already large household to possible financial distress. Hence, the households with children are willing to pay a higher premium for cleaner tomatoes to avert the risk of illness and subsequent costs. This finding spells out a clear and strong policy implication in favour of cleaner food production, which could reduce the burden on health infrastructure in addition to averting the health expenditures of relatively large households, safeguarding them from slipping into a poverty-trap.

These findings help in answering the second research question, regarding consumer WTP for the tomatoes produced with the proposed changes in existing agricultural practices, stated in the introduction section of this study.

Interestingly, findings of this research revealed that the consumer WTP is higher than farmer WTA to implement the proposed changes, except drip irrigation for which farmers have a negative WTA. This means that the proposed changes are economically viable, suggesting that the market can offer adequate compensation to farmers for producing cleaner tomatoes. This important discovery validates the core thesis of this research that market-based mechanisms present a viable solution to the problem of agricultural pollution and to thin environmental compliance and thus poor food quality standards in Pakistan. While reducing administrative and regulatory burden, market-based approaches can save huge health and environmental costs to the Pakistani economy, and the present study presents empirical evidence to support the use of market-based approaches for cleaner food production instead. More generally, it demonstrates that market-based mechanisms are viable in Pakistan which has instead traditionally relied upon regulatory measures, thus justifying the initial motivational hunch in proposing this idea for doctoral level research.

This part of the conclusion answers the third research question that how the findings of this research could inform policy makers in the design of market-based mechanisms to modify the existing agricultural practices?

The results of this study present interesting contrasts and powerful implications regarding cleaner food production in Pakistan. The analysis clearly disentangles the health, environment and compliance aspects of food production, which generates thought-provoking insights that can facilitate a stimulating debate among consumers, farmers and food businesses in addition to offering actionable information and policy suggestions for policy makers in the relevant government departments.

Analysis presented in Chapter 6 answers the fourth research question raised in the introduction chapter (Chapter 1) of this thesis regarding consumer preferences and WTP for the reduction of pesticide and fertiliser use and adoption of efficient irrigation technologies in tomato crop production under different inspection regimes.

The next chapter (Chapter 7) presents the overall conclusion and policy implications of this thesis.

Chapter 7 Conclusion and policy implications

Conducting applied research in a social norms-driven society to investigate the choices of relatively less educated respondents involves meticulous work as well as a fair amount of painstaking labour to accomplish. Needless to say, engaging with farmers in low-income and low-literacy rural settings to administer primary surveys is not only strenuous and tiresome, but is also massively challenging in many ways. However, these much needed yet laborious efforts can become futile if adequate attention is not paid to draw meaningful conclusions from such work. Every effort is made in this chapter not only to clearly outline the main conclusions drawn from the findings of this research, but also to translate those findings as effectively and precisely as possible into *concrete policy inputs.* Therefore, the insights of this research will elucidate its significance by presenting its less obvious and more crucial aspects, and in particular show how an understanding of the social dimensions of farming provide the means by which policy makers can engineer effective and *targeted* interventions.

The next section presents a summary of key findings of this research.

7.1 Key findings

The use of the DCE approach in this study has contributed to a deeper understanding of farmers' as well as consumers' preferences for sustainable agricultural practices, and hence the underlying pattern of their monetary valuation. This methodology enabled the discovery and quantification of the trade-offs respondents make regarding the attributes of cleaner tomato production, which furnishes actionable information for key stakeholders of this research. In addition, DCE has allowed the use of key socio-demographic covariates to derive respondents' utility as well as welfare estimates for selected attributes, which helps in disentangling their impact and subsequently investigating their role in deriving the preferences. Application of discrete choice experiment (DCE) methodology in this research reveals that models estimated in preference-space and price-space return comparable results. The mixed logit model in price-space demonstrated a better fit for the farmer data; however, the mixed logit model in preference-space outperforms the model in price-space for consumer data. Note that the price-space models do not incorporate interactions between alternative attributes and respondents characteristics. Therefore, the preference-space models with interactions are not nested into the price-space models. This allows the preference-space model with interactions to fit the data better than the price-space models without contradicting theory.

Findings reveal that farmers prefer the changes in current agricultural practices used in tomato cultivation in Khushab, for example, they are willing to reduce pesticide and fertiliser use. However, they are disinclined to adopt drip irrigation technology which is due to drip irrigation's higher cost and the uncertainty of farmer land tenure (e.g. length of tenancy), which results in the insecurity of any potential investment in drip irrigation. This is an important finding, which implies that insecure land tenancy is a barrier to the adoption of efficient irrigation technologies amongst tomato farmers in Khushab. This finding also implies that reduction in the cost of drip technology by means of some subsidy could improve its uptake, and hence the irrigation efficiency. Consumers, on the other hand, demonstrate a strong preference for the proposed changes and place a high value on all attributes of the proposed changes, including inspection. While the farmer survey discovered interesting social phenomena influencing their preferences (i.e. the role of land tenancy in the adoption of drip irrigation), investigation of consumer preferences makes a similarly compelling case for the composition of a household (i.e. the presence of children) and a concern for intergenerational equity playing an equally causal role in informing consumer choices.

Welfare estimates show that farmer WTA for drip irrigation is negative, indicating that farmers are willing to forgo some earnings to avoid the adoption of drip irrigation technology. However, farmers have positive WTA's for pesticide and fertiliser use reductions and their WTA's for greater reductions are higher. Moreover, farmer WTA's are higher for greater reductions in pesticides than that for greater reductions in fertilisers which indicates that farmers demand relatively higher compensation for pesticide reductions. The prevalence of large standard deviations of some of the WTA's indicate that a significant fraction of survey participants require large amounts of money to adopt the proposed changes which shows the presence of preference heterogeneity. However, this could also be due to the choice of distributions used in modelling farmer preferences.

As observed for WTA estimates, the estimated distributions of WTP also show the prevalence of large standard deviations, indicating that a significant fraction of consumers is willing to pay large amounts of money to have the attributes of proposed changes which reflects a high degree of preference heterogeneity in consumer choices, which could also be due to the choice of distributions for the random coefficients. Consumers, however, place a positive and significant value on all proposed changes and the differences in WTP for each attribute of cleaner tomato production clearly translate their concerns as well as perceived risks. For example, consumers have the highest WTP for the inspection attribute, which shows their concern about the actual implementation of the stated changes, as compliance of food quality standards is a serious issue in Pakistan. However, relatively high consumer WTP for efficient irrigation technologies indicates their preference for water conservation, and hence the social value of the environment as they do not stand to benefit personally from the improvement in irrigation efficiency.

An intriguing finding from this research shows the influence of household composition on respondents' preferences for the proposed changes in current agricultural practices. For example, consumer WTP for greater fertiliser reductions and four-time inspection have a positive correlation with the presence of children in a household. While this seemingly points towards parental concerns about the quality of food their children consume, a more plausible interpretation is that consumers perceive an increase in the risk of illness and the subsequent unexpected health costs with the increase in the number of children, exposing an already large household to likely financial distress. Hence, the households with children are willing to pay a price premium on cleaner tomatoes to avert the risk of illness and the related costs, which rises with the increase in the number of children. Results of farmer surveys also show that educated farmers derive more disutility from existing use of pesticides, and thus prefer a lower use of pesticides instead.

The above presented key findings of the thesis provide the answers to the third and fourth research questions, regarding farmer and consumer preferences and WTA's and WTP's, outlined in the introduction chapter (Chapter 1) of this thesis.

The most powerful and perhaps compelling finding of this research is that the consumer WTP for the proposed changes (except drip irrigation) in tomato cultivation is higher than the farmer WTA to implement those changes. This means that the proposed changes are economically viable, suggesting that the market can offer adequate compensations to farmers for producing cleaner tomatoes. This important discovery validates the core thesis of this research, which maintains that market-based approaches can help solve the problem of agricultural pollution as well as thin environmental compliance and thus poor food quality standards in Pakistan. Furthermore, while reducing administrative and regulatory burden, market-based approaches can save huge health and environmental costs to the Pakistani economy, not to mention the possible deaths associated with the overuse of agrochemicals. This study presents solid empirical evidence to support the contention in favour of the use of market-based approaches for cleaner food production instead. By the same token, this research indicates that the use of market-based mechanisms could be viable in Pakistani agriculture, justifying the initial motivational hunch in proposing this idea for doctoral level research.

These findings provide the answer to the fifth research question that investigates the role of DCE to inform policy makers to design economic incentive schemes as a market-based mechanism for the modification in existing agricultural practices used in tomatoes.

Farmer and consumer perceptions of current agricultural practices used in tomato crop reveal that farmers and consumers are aware of the health and environmental impacts of pesticide and fertiliser use in the tomato crop. While farmers generally consider that the proposed reductions in the use of pesticides and fertilisers would decline the tomato crop yield, a significant fraction believes that the proposed reductions would be benign to the tomato crop. Empirical analysis uncovered that farmers who own their farmland and those who have received the training to apply agrochemicals are more likely to consider proposed reductions as harmless to the tomato crop. However, as expected, farmers who have experienced a greater number of major disease outbreaks in the past and those who have perceived a greater decrease in tomato price due to reduction in the use of pesticides are less likely to believe that the proposed reductions would be undisruptive. This shows that farmer training and education, land ownership, and their prior experience drive the perceptions of the proposed changes.

Results show that majority consumers are aware of the amounts of agrochemicals used in tomato crop. Similarly, consumers believe that the consumption of organic vegetables is good for their health and the natural environment. Empirical results disclosed that consumer households with greater tomato consumption and a greater number of children have negative; whereas, consumer education, understanding of organic food, frequent reading of food ingredients, food adulteration news, and positive perception of their health have positive impact on consumer knowledge of amounts of agrochemicals being used in tomato crop, and their understanding of organic vegetable. This implies that while large households with greater food expenditures are less likely to be aware of the existing agricultural practices used in tomato cultivation; consumer education, awareness, and food and health consciousness may affect consumers' understanding of the food production practices.

These findings provide the answer to the first and second research questions regarding the farmer and consumer perceptions of the existing agricultural practices used in tomato crop and the proposed changes to adopt sustainable agriculture?

The results of this study present interesting contrasts and powerful implications for the uptake of sustainable agricultural practices in Pakistan. The DCE analysis clearly disentangles the health, environment, and compliance aspects of food production and generates thought-provoking insights that can facilitate a stimulating debate among consumers, farmers, and food businesses in addition to offering actionable information and suggestions for policy makers in the relevant government departments. This research expands the investigation of farmer choices from *individual* to *social* aspects of choice in a rural tribal setting. In this way, this work opens-up an avenue to depart from a traditional and narrow view of choice to a broader, more holistic and context specific discussion of choice behaviour, which is a unique feature of rural tribal society in Pakistan.

The next section presents the key policy implications of this research.

7.2 Policy implications

This section briefly outlines the main policy implications emanating from the key findings of this research, which are mainly aimed for relevant departments to use as input in designing policies for sustainable agriculture in Pakistan. The present research has significant policy relevance as the findings could inform policy makers in designing several interventions outlined in the Agriculture and Food Security Policy, the National Water Policy, and the National Sustainable Development Strategy of Pakistan. For example, adoption of efficient irrigation, improvement in farm gate price, and agricultural sustainability for health- and environment-friendly food production are some of the common issues that these policies have highlighted, and the findings of the present research provides useful insights and actionable information on these issues. Nevertheless, this section also presents useful suggestions for other stakeholders such as food businesses and researchers who use the DCE methodology in similar contexts.

A key finding that supports the fundamental argument of this research is that consumer WTP for the proposed reductions in agrochemical use is higher than the farmer WTA estimates, which provides solid empirical evidence to policy makers in favour of design and implementation of market-based approaches to encourage and incentivise cleaner food production in Pakistan. This supports the contention that the use of market-based mechanisms in Pakistani agriculture, which instead traditionally relied upon regulatory measures, are feasible.

This research reveals that DCE, as a methodology, is an equally powerful and appropriately robust tool for applied research in a low-income, low-literacy rural setting, provided that it is carefully designed and implemented. The methodology has allowed to uncover and quantify the trade-offs respondents make about the different attributes of cleaner tomato production, and thus furnishes useful information in order to allow policy makers to focus on specific aspects of problems and design more targeted interventions while considering the population's differentiated needs. This, as a result, clearly signifies that DCE could be used to generate the empirical evidence to design food and agricultural policies in this and other similar contexts in developing countries. Since the DCE application in this analysis also uncovers some context-specific *socio-demographic attributes* that drive the respondents' choices in study areas, the power of DCE as a tool can also be exploited in exploring observed interpersonal heterogeneity in citizens' preferences in similar customs-driven rural tribal societies, where decision-making is influenced by social-norms and communal considerations in addition to pure profit motives.

Findings on farmer preferences for sustainable agricultural practices show that insecure land tenancy, social benefit of water conservation at farmers' private cost, fixed cost of water, and greater installation cost of drip irrigation are some of the main barriers to the adoption of efficient irrigation technology amongst tomato farmers. Due to a fixed water cost and hence a lack of penalty on flood irrigation, adoption of drip irrigation has no incentive. Furthermore, adoption of drip irrigation has an opportunity cost. Hence, policy makers need to eliminate the negative incentive for adoption of flood irrigation in terms of flat water price. Instead, the efficient irrigation (drip) should be incentivised. Furthermore, as the informal land tenancy functions as an impediment to the adoption of irrigation technologies and hence sustainable farming practices, the government must facilitate more formal and secure land tenancy arrangements to enable tenant farmers to invest in agricultural technologies. This could contribute towards efficient use of resources and hence to a more sustainable food production system, while at the same time empowering tenant farmers. Furthermore, policy makers must pay adequate attention to *land ownership structure* while designing agricultural policies in Pakistan.

Consumers' relatively higher valuation for irrigation water conservation implies that they retain and enjoy a bequest value for future resources, thus indicating that *intergenerational equity* is a significant driver of consumer choice behaviour. This suggests that the environment has a significant contribution to citizens' social wellbeing and gives a strong justification to policy makers for the allocation of resources to environmental conservation. Furthermore, intergenerational equity also translates to private concerns, as consumer households with children have a higher WTP for some of the proposed changes. This provides a clear and strong policy implication in favour of cleaner food production, which would reduce the burden on health infrastructure in addition to averting the health expenditures of relatively large households, safeguarding them from slipping into a poverty-trap.

It is noteworthy that among all attributes of cleaner tomato production, consumers have the highest WTP for inspection of the proposed changes, which stresses that consumers perceive serious inadequacies in Pakistani food safety standards, and hence have a lower confidence in food quality monitoring systems in Pakistan in general. This calls for an urgent need for accountability in food industries to ensure the stringent implementation of food safety standards. Similarly, educated farmers' more disutility from pesticide use suggests that education could be a key entry point for policy makers to implement the proposed changes in existing agricultural practices amongst Pakistani farmers. In this regard, agricultural extension services can play a powerful role by educating farmers regarding the use of sustainable agricultural practices.

Since this research reveals the influence of unique social context on respondents' choices and welfare estimates, and the results necessitated careful interpretation while placing those in the study context, it is suggested that researchers carefully consider such factors (i.e. socio-cultural phenomena) as if a seemingly counter-intuitive result is interpreted carefully, it can yield powerful policy suggestions. Furthermore, this also has important implications for the design and implementation of DCEs, including explanation of experiments and simulation of the interview environment.

DCE analysis of citizens' choices regarding cleaner tomato production also provides actionable information to food businesses. For example, findings on welfare estimates can inform businesses interested in exploiting market niches in the cleaner food production sector in Pakistan. These businesses can invest in cleaner food and sell relatively cleaner produce against higher premiums in a more targeted market consisting of relatively affluent urban areas.

Farmer awareness of the health and environmental impacts of pesticide and fertiliser use suggests that they understand the risk of intensive farming and might be willing to adopt the alternatives to the existing farming practices. Considering the changes required for the implementation of sustainable agricultural practices, these results are very encouraging. Since farmers with ownership rights and training to apply the agrochemicals have a perception that the proposed reductions are harmless to the tomato crop, policy makers should target these groups of farmers to ensure the effective delivery of agricultural extension services and encourage the adoption of sustainable agricultural production methods.

A lack of awareness with regards to the agricultural practices amongst large consumer households with greater food expenditures shows that these households might be less keen about the quality of the food. This result has important implications for a more equitable and inclusive food production and supply system whereby food and agriculture agencies ensure that cleaner food is affordable for low-income households with greater food expenses. Results of consumer understanding of different farming practices indicate that consumer education, awareness, and food and health consciousness can influence the demand, and hence the availability of cleaner food which may pave the way to the uptake of sustainable agricultural practices and cleaner food production.

In what follows is a discussion on the market-based mechanism.

7.3 Practical use of study findings and a way forward

7.3.1 Market-based mechanisms

The predominant method to the management of natural resources including controlling pollution in many countries has been command-and-control based regulatory approaches (González-Eguino, 2011). However, there is a growing recognition that command-and-control based regulatory approaches are weak and insufficient. There are two reasons for this view, one, holding all producers to the same requirement is inappropriate and can be counterproductive, and two, the command-and-control system limits the freedom of affected producers to choose among the means of compliance. This, as a result, makes compliance to the environmental standards more expensive as it is not only costly in terms of enforcement, but it is also pricy to comply with (Jay and Rosato, 2002; González-Eguino, 2011; Zhang, 2013).

Furthermore, producers do not have any incentive to reduce pollution, and in case of a weak government, enforcement might be selective and may result in rent-seeking activities. This distaste for the command-and-control approach appears to go hand in hand with growing interest in market-based approaches (Filoche, 2017). In addition, it is believed that the behavioural change is more likely to occur through economic incentives rather than applying force. In this regard, economic incentives could be aligned with self-interests of the private sector that could lead to the development of markets for environmental goods and services (ADB, 2008).

For this purpose, market-based mechanisms are proposed which could be self-sustaining and could provide correct market signals for environmental protection. Market-based mechanisms are based on the idea of economic incentives (Filoche, 2017), for example, it is possible to provide businesses with the same types of incentives that they face in markets to motivate them to protect the environment. Initially, market-based mechanisms were introduced as flexible instruments to mitigate the green-house-gases through emission trading, but later these tools have been used in other areas such as payment for ecosystem etc. Now, market-based mechanisms for pollution control are popular both in the environmental economics literature and in real-world policymaking (Jay and Rosato, 2002).

Market-based mechanisms refers to market-based instruments (MBIs) which have been gaining ground in environmental and climate policy in recent years as they play a crucial role in achieving a resource efficient economy (González-Eguino 2011). The economic rationale provided for using MBIs is that these instruments can help correct the market failures in a cost-effective way (Greiner, 2014). Research claims that if properly designed and implemented, MBIs can achieve any desired level of pollution reduction at the lowest social cost by offering incentives for pollution reduction to those firms that can realize these reductions at the lowest cost (Strahilevitz, 2000). MBIs encourage behavioural change through market signals by providing economic incentives to agents and can complement regulations (Filoche, 2017).

Furthermore, it is also recognised that management of environmental problems by prices is superior to management through command-and-control approaches (ADB, 2008). The empirical evidence suggests that MBIs are likely to have greater impacts over time than command-and-control approaches on the innovation and diffusion of environmentally friendly technologies (Jaffe et al., 2002) which can revolutionise environmental protection. Some of the examples of MBIs are taxes, charges, subsidies, marketable or tradable permits (cap-and-trade systems), eco-labelling, licenses, and property rights. However, the most widely used MBIs are price-based such as taxes, charges, subsidies, and levies. Most of the environment related MBIs that are being used globally are fiscal, e.g. tax and instruments (Pirard, 2012).

MBIs are also helpful in addressing the problem of resource efficiency as additional costs or benefits caused by a particular instrument can induce a more material and natural resource efficient production and/or consumption behaviour by consumers and producers. For example, in the context of present research, MBIs can be very useful in ensuring the tomato farmers' compliance to health and environmental standards, and thus the judicious use of agricultural inputs such as agrochemicals and irrigation water. As such MBIs can discourage intensive farming that has negative consequences for human health and the natural environment in study areas, which in turn can facilitate the transition of agriculture from crop intensification to health- and environmental-friendly sustainable farming.

The objective of using the idea of market-based mechanisms for the present research was to explore the potential of economic incentives as specific policy measures for stimulating cleaner food production and supply and encouraging households to consume the health- and environment-friendly cleaner food. The most suitable policy options in the context of this research in terms of MBIs are taxes, subsidies, and eco-labelling. These are mostly price-based and information-based instruments which are based on positive and negative incentives. The price-based instruments are assumed to have a voluntary character which often involve close collaboration between government and private initiatives.

The main reason for proposing these three policy options is that they are most appropriate and potentially more effective to achieve the desired objective to implement the proposed changes. For example, results of this research show that farmers in general and tenant farmers in particular are reluctant to adopt the drip irrigation technology owing to its higher installation cost and uncertainty of land tenures. The suitable MBI to incentivise the adoption of drip irrigation technology in this context could be a subsidy which motivates farmers to install drip irrigation technology that could save a significant amount of irrigation water which is already scarce in Pakistan since it is a water-stressed country. On the other hand, if farmers do not comply despite having an incentive in the form of subsidy, they should be penalised with a negative incentive such as a tax that they pay for not installing the drip irrigation as they contribute to an environmental problem that has implications for society.

Similarly, findings of the present research suggest that farmers are willing to adopt the proposed reductions in the use of agrochemicals without asking for a lot of compensation, the consumers' willingness to pay a relatively higher price premium on cleaner tomatoes has made it even more promising. The most suitable policy option in terms of MBIs to implement the proposed reductions in the use of agrochemicals is eco-labelling which could be used as a credence attribute to signal the quality of the cleaner produce which would also be an incentive for the producers.

The above discussion answers the last research question outlined in the introduction (Chapter 1) of this thesis that inquires how the DCE could inform policy makers to design economic incentive schemes as a market-based mechanism for the modification of existing agricultural practices.

The next section discusses the potential strengths and weaknesses of eco-labelling which is a market-based instrument and a policy tool to signal the credence attribute of a product.

7.3.2 Eco-labelling

Eco-labelling is a process to attach environmental information to products that allows consumers to choose the ones that have been produced in more environmental-friendly ways and enables producers to pass on higher production costs to consumers (Greiner, 2014). It is the result of a quality assurance process such as certification of the underlying agricultural practice following a process or criteria (de Haes and de Snoo, 2010). The process may assure consumers that governments watch over the presentation of goods and protect them (Dimara and Skuras, 2005). The present research has a similar context as it proposes to use the labels for health- and environment-friendly cleaner tomatoes which will be produced using sustainable agricultural production methods. The underlying agricultural process in the context of present research is the reduction in the concentrated use of agrochemicals and irrigation water or judicious use of agricultural inputs which will be certified after proposed inspection of the tomato farms.

Labels are a cost-effective way of communicating information to consumers to assist them in making purchase decisions considering the quality of the product, hence they act as a credence attribute to identify the product quality (Dimara and Skuras, 2005; Bacarella et al., 2015; Miller and Cassady, 2015; Ingrassia et al. 2017). Each label conveys a set of characteristics that provides information about the product (Bacarella et al., 2015). For example, the tomatoes produced with the lower use of agrochemicals and irrigation water in Khushab would be relatively cleaner and environment-friendly and consumers in Islamabad could easily identify these through a label.

Food safety issues often result from the asymmetric information between consumers and suppliers regarding the product specific attributes, and food labels are a powerful tool for suppliers to convey information to the consumers (Bacarella et al., 2015). Since consumers have some degree of loyalty to firms which produce high quality products, labelling helps differentiate the products and consumers may learn about food attributes through informational labelling that signal the quality (Dimara and Skuras, 2005; Ingrassia et al. 2017). As indicated above in the policy implications section, vegetable businesses in study areas can exploit the market niches of health- and environment-friendly cleaner vegetable supply and sale by using product differentiation strategy, and they can capitalize on the image of responsible businesses using labels.

Food labels intended to communicate scientifically proven health benefits associated with consuming a particular food enable consumers to pay attention to important information about food that can facilitate their dietary choices (Miller and Cassady, 2015). In this regard, nutritional characteristics and the content level of various chemical substances are well known credence attributes. Hence, it is possible to improve food safety and enhance consumer confidence through the food labels, which provide credence information (Ingrassia et al. 2017). In short, food labels are a source of information about the ingredients and nutrition value, provide awareness to people about their diet, facilitate a fair comparison between products, motivate people to eat healthier, discourage the production and sale of unhealthy products, and may increase overall health of consumers.

Nevertheless, claims on food labels sometimes have little impact on product evaluations and may even be misleading and confusing (Miller and Cassady, 2015). This also applies to the context of present research due to relatively lower education and consumer inclination to read food ingredients/labels. The efficiency of labelling as an informational source has been seriously questioned as it depends on the importance consumers deem the labelled information and if the information is comprehensible (Dimara and Skuras, 2005). For example, consumers can misinterpret the food labels and thus misalign their personal preferences and their actual food purchases (Messer et al, 2017). Beside this, information on food quality attributes can be biased, inaccurate, and unfavourable depending on the way the information is conveyed to the consumer, not to mention consumers' ability and willingness to process that information (Ingrassia et al. 2017). These problems have a higher likelihood in food systems with poor compliance to the health and safety standards, and this unfortunately includes the context of the present research.

Likewise, food stores offer a lot of products and some products have a lot of variety and consumers find it difficult to process too much information or information delivered in a complex format, hence they might not use it due to the time constraint (Dimara and Skuras, 2005). Moreover, the process of consumption is not homogeneous, i.e. not all consumers have the same values and want the same features, and despite agreeing with certain issues such as sustainability, they may not necessarily change their consumption behaviour (Bacarella et al., 2015). Another issue with food labels is that these labels can stigmatize food produced with conventional processes even when there is no scientific evidence that this food causes harm or is compositionally any different (Messer et al, 2017).

In addition, food labels only give basic information that may not cater to the individual circumstances. For example, often food labels do not differentiate between different ingredients such as good and bad fat. Similarly, some claims are deceptive as producers often try to mask unhealthy ingredients. In this way, consumer trust can be exploited, and food labels may take away accountability from people. Hence, people may end up buying the wrong products. Besides, some of the labelling of slimming and diabetic products have also not yet been addressed which means that people who want to lose weight or have diabetes or insulin resistance will be in the dark about any food products that may or may not be beneficial to their condition.

This means that there are also the issues of moral hazard and adverse selection in eco-labelling. For example, the problem of information asymmetry in eco-labelling may lead to moral hazard and adverse selection. One way to mitigate the adverse selection generated by product credence attributes could be the involvement of third parties with an established reputation for credibility (Bougherara and Grolleau, 2005). However, this arrangement might not be cost effective for the producers and/or consumers of the product.

Furthermore, in an average market, there are products of unknown environmental quality, products with vague claims, and certified products. Moral hazard and adverse selection can occur where some of the product attributes indicate credence (Grolleau and Caswell, 2006). For example, in the context of present research, the claimed reductions in the use of agrochemicals might be more than their actual implementation. To address these issues, there should be some control mechanisms including penalties for producers in case of false declarations with regards to their products, otherwise there will be consumer welfare loss due to moral hazard (Valentini, 2005).

Moreover, in the presence of moral hazard and adverse selection, there will be less reward for high quality producers and inadequate penalty for low quality producers (Grolleau and Caswell, 2006). The credibility of the certification agency that labels the product, the comprehensiveness of the monitoring and certification process, and the cost of the monitoring and certification process also affect moral hazard (Valentini, 2005). The issues with regards to moral hazard and adverse selection however could be mitigated by arranging frequent inspections and allowing ordinary consumers to visit the food production sites.

7.4 Thesis answers to the research questions

Below is a brief description of how the work presented in this thesis has addressed the research questions outlined in the introduction chapter (Chapter 1).

1. ***What are farmer and consumer perceptions of the existing agricultural practices used in tomato crop and the proposed changes to adopt sustainable agriculture?***

   This research question is addressed in Chapter 4 of this thesis where results regarding the farmer and consumer perceptions of the existing agricultural practices used in tomato crop and the proposed changes to adopt sustainable agriculture are presented.

2. ***What are the factors that explain farmer and consumer perceptions of existing agricultural practices and proposed changes?***

This research question is also answered in Chapter 4 by conducting the empirical analysis of the drivers of farmer and consumer perceptions which explores the socio-demographic and other factors that explain farmer and consumer perceptions in study areas.

3. ***What are farmer preferences and WTA's for the reduction in the use of pesticides and fertilisers and adoption of efficient irrigation technologies in the tomato crop?***

   This research question is responded to in Chapter 5 which includes the analysis of farmer preferences and their WTA's for the proposed changes in existing agricultural practices to adopt sustainable agriculture.

4. ***What are consumer preferences and WTP's for the reduction in the use of pesticides and fertilisers and adoption of efficient irrigation technologies in the tomato crop?***

   This research question is addressed in Chapter 6, which presents the results of a DCE analysis of consumer preferences for the proposed changes in existing agricultural practices to adopt sustainable agriculture.

5. ***How could the DCE inform policy makers to design economic incentive schemes as a market-based mechanism for the modification in existing agricultural practices used in tomato crop?***

   Both Chapter 5 and Chapter 6 answer this question, for example, farmer WTA's and consumer WTP's provide ample information and insights about the use of market-based mechanisms. A powerful finding in this regard is that consumer WTP's for the proposed changes are higher than the farmer WTA's.

7.5 Study limitations

This section outlines some of the main limitations of the research presented in this thesis.

A limitation of this study is regarding the primary data that was collected using questionnaires. Since this research primarily uses the DCE approach and involves the experimental designs to collect the data, it was not possible to use longer questionnaires. Hence, only necessary information was gathered using the questionnaires. As DCE surveys require more effort, time, and resources and the longer questionnaires would have compromised the data quality due to longer duration of interviews, tiring effect, and response heuristics. Thus, considering this trade-off between data quality and quantity; information regarding household assets and wealth, farm machinery, and family labor was not included in the questionnaire. The future research may gather this information to incorporate it in the analysis to examine its impact on farmer choices.

Similarly, heterogeneity in the use of agrochemicals is not investigated in this research. However, it is an important aspect as some farmers might use more agrochemicals than other farmers. This could happen due to several factors such as variation in soil fertility, greater crop vulnerability to pests, affordability, or other factors which contribute to their risk perceptions. Nevertheless, this aspect is crucial as different farms might have different input requirements and subsequent levels of pollution. An analysis of the heterogeneity in the use of agrochemicals would be a good exercise for future research.

The DCE analysis carried out with farmers as well as consumers is tomato crop specific, hence the respondents' preferences as well as welfare estimates for the stated changes may not be used for the decision making for other vegetables. Furthermore, this research investigates the preferences of small-scale farmers in specific locations, which may not be the same in other places. This difference can be even more significant for the large farmers, who will possibly see the proposed changes in different ways. The future research could expand the analysis to multiple crops and include large farmers' sample in analysis as well. This will allow comparison of farmer preferences across the crops, farm size, and locations, which could give a broader picture and inform food and agricultural policies more holistically.

While the present research offers useful policy suggestions with regards to the demand and supply of sustainable agriculture and cleaner food production, there is a room for policy analysis in context of market-based mechanisms by using the results of farmers' and consumers' perceptions, preferences, and welfare estimates. The future research could use these findings and design the implementation strategy for the sustainable agriculture and cleaner food production in Pakistan.

The consumer sample for this research was drawn from Islamabad, the capital of Pakistan, which is a relatively more educated and affluent setting. As a result, consumers demonstrated a keen interest in cleaner food production. However, the consumer preferences as well as their WTP for a price premium for cleaner produce may appear different in other low-income and less-educated settings. The future research could include sample from diverse settings and it will allow to simulate more representative consumer WTP.

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Appendices

Appendix – A Negene syntax and design outputs

Appendix – I presents the Ngene syntax used to create the choice situations which were presented to the respondents in pilots as well as final surveys conducted for this research. This also includes the additional output such as efficiency measures and correlation matrix.

<u>Optimal orthogonal design used in first pilot</u>

A1: Negene design syntax

Design								
;alts = Alt1, Alt2								
; block= 12, minsum, total(3 mins)								
;rows = 72								
;orth = ood								
;model:								
U(Alt1) = b1 * X1[0,1,2] + b2 * X2[0,1,2] + b3 * X3[0,1,2] + b4 * X4[0,1,2] + b5 * X5[0,1,2,3,4,5] /								
U(Alt2) = b1 * X1[0,1,2] + b2 * X2[0,1,2] + b3 * X3[0,1,2] + b4 * X4[0,1,2] + b5 * X5[0,1,2,3,4,5]								
$								

A2: D-optimality of optimal orthogonal design

OOD optimality measures	
D optimality	0%

A3: Correlations (Pearson Product Moment)

Attribute	alt1.x1	alt1.x2	alt1.x3	alt1.x4	alt1.x5	alt2.x1	alt2.x2	alt2.x3	alt2.x4	alt2.x5	Block
alt1.x1	1	0	0	0	0	-0.5	0	0	0	0	-0.02957
alt1.x2	0	1	0	0	0	0	-0.5	0	0	0	0
alt1.x3	0	0	1	0	0	0	0	-0.5	0	0	0.009855
alt1.x4	0	0	0	1	0	0	0	0	-0.5	0	0
alt1.x5	0	0	0	0	1	0	0	0	0	0.142857	0.014135
alt2.x1	-0.5	0	0	0	0	1	0	0	0	0	0
alt2.x2	0	-0.5	0	0	0	0	1	0	0	0	0.014783
alt2.x3	0	0	-0.5	0	0	0	0	1	0	0	-0.00493
alt2.x4	0	0	0	-0.5	0	0	0	0	1	0	-0.02957
alt2.x5	0	0	0	0	0.142857	0	0	0	0	1	-0.02827
Block	-0.02957	0	0.009855	0	0.014135	0	0.014783	-0.00493	-0.02957	-0.02827	1

A4: MNL efficiency measures for optimal orthogonal design

D error	0.023126				
A error	0.024444				
B estimate	100				
S estimate	0				
Prior	b1	b2	b3	b4	b5
Fixed prior value	0	0	0	0	0
Sp estimates	Undefined	Undefined	Undefined	Undefined	Undefined
Sp t-ratios	0	0	0	0	0

A5: MNL fisher matrix

Prior	b1	b2	b3	b4	b5
b1	36	0	0	0	0
b2	0	36	0	0	0
b3	0	0	36	0	0
b4	0	0	0	36	0
b5	0	0	0	0	90

A6: MNL covariance matrix

Prior	b1	b2	b3	b4	b5
b1	0.027778	0	0	0	0
b2	0	0.027778	0	0	0
b3	0	0	0.027778	0	0
b4	0	0	0	0.027778	0
b5	0	0	0	0	0.011111

A7: MNL choice probabilities

Choice situation	alt1	alt2	Choice situation	alt1	alt2	Choice situation	alt1	alt2
1	0.5	0.5	25	0.5	0.5	49	0.5	0.5
2	0.5	0.5	26	0.5	0.5	50	0.5	0.5
3	0.5	0.5	27	0.5	0.5	51	0.5	0.5
4	0.5	0.5	28	0.5	0.5	52	0.5	0.5
5	0.5	0.5	29	0.5	0.5	53	0.5	0.5
6	0.5	0.5	30	0.5	0.5	54	0.5	0.5
7	0.5	0.5	31	0.5	0.5	55	0.5	0.5
8	0.5	0.5	32	0.5	0.5	56	0.5	0.5
9	0.5	0.5	33	0.5	0.5	57	0.5	0.5
10	0.5	0.5	34	0.5	0.5	58	0.5	0.5
11	0.5	0.5	35	0.5	0.5	59	0.5	0.5
12	0.5	0.5	36	0.5	0.5	60	0.5	0.5
13	0.5	0.5	37	0.5	0.5	61	0.5	0.5
14	0.5	0.5	38	0.5	0.5	62	0.5	0.5
15	0.5	0.5	39	0.5	0.5	63	0.5	0.5
16	0.5	0.5	40	0.5	0.5	64	0.5	0.5
17	0.5	0.5	41	0.5	0.5	65	0.5	0.5
18	0.5	0.5	42	0.5	0.5	66	0.5	0.5
19	0.5	0.5	43	0.5	0.5	67	0.5	0.5

20	0.5	0.5	44	0.5	0.5	68	0.5	0.5
21	0.5	0.5	45	0.5	0.5	69	0.5	0.5
22	0.5	0.5	46	0.5	0.5	70	0.5	0.5
23	0.5	0.5	47	0.5	0.5	71	0.5	0.5
24	0.5	0.5	48	0.5	0.5	72	0.5	0.5

<u>D-efficient Bayesian design used in second pilot</u>

Ngene syntax of D-efficient Bayesian design which was used in the second pilot surveys. D-efficient Bayesian design was created using the priors which were collected from first pilot. D-efficient Bayesian design has 12 blocks and 72 rows.

A8: Negene syntax

Design;						
alts = Alt1, Alt2;						
block= 12, minsum, total(3 mins);						
rows = 72;						
eff = (mnl,d,mean);						
model:						
U(Alt1) =						
b1.dummy[(n,0.25,0.4)|(n,0.65,0.4)] * irr[1,2,0] +						
b2.dummy[(n,-0.4,0.4)|(n,-0.5,0.7)] * fer[1,2,0] +						
b3.dummy[(n,0,0.3)|(n,0.24,0.4)] * pes[1,2,0] +						
b4.dummy[(n,0.6,0.4)|(n,0.7,0.5)] * ins[1,2,0] +						
b5[(u,0.05,0.5)] * subs[2,4,6,8,10] /						
U(Alt2) = b1.dummy * irr +						
b2.dummy * fer + b3.dummy * pes + b.dummy4 * ins + b5 * subs						
$						

A9: MNL efficiency measures

		Bayesian								
	Fixed	Mean	Std dev.	Median	Minimum	Maximum				
D error	0.088642	0.104076	0.01108	0.103049	0.07857	0.152272				
A error	0.136741	0.163567	0.0179	0.161385	0.123555	0.258062				
B estimate	85.90512	74.74983	6.438856	74.52992	52.50344	94.72535				
S estimate	8.83368	39183.28	330607.7	135.2941	5.781435	3488986				
Prior	b1(d0)	b1(d1)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4(d0)	b4(d1)	b5	b
Fixed prior value	0.25	0.65	-0.4	-0.5	0	0.24	0.6	0.7	0.275	0
Sp estimates	8.27525	1.475972	3.298542	2.384982	Undefined	8.83368	2.368466	1.897623	0.489487	Undefined
Sp t-ratios	0.681343	1.613307	1.079183	1.269152	0	0.659455	1.273569	1.422824	2.801468	0
Sb mean estimates	15897.21	168.0298	17536.89	613.475	1462.588	690.0778	580.1548	2516.413	1.437552	Undefined
Sb mean t-ratios	0.934951	1.471679	1.142531	1.518385	0.619516	0.934008	1.159731	1.328669	2.385135	0

A10: MNL choice probabilities

Choice situation	alt1	alt2	Choice situation	alt1	alt2	Choice situation	alt1	alt2
1	0.485004	0.514996	25	0.58904	0.41096	49	0.670401	0.329599
2	0.375194	0.624806	26	0.634136	0.365864	50	0.620106	0.379894
3	0.676996	0.323004	27	0.415809	0.584191	51	0.668188	0.331812
4	0.624806	0.375194	28	0.571996	0.428004	52	0.668188	0.331812
5	0.356635	0.643365	29	0.620106	0.379894	53	0.377541	0.622459
6	0.833411	0.166589	30	0.562177	0.437823	54	0.752129	0.247871
7	0.601088	0.398912	31	0.299433	0.700567	55	0.514996	0.485004
8	0.356635	0.643365	32	0.830616	0.169384	56	0.389361	0.610639
9	0.425557	0.574443	33	0.908045	0.091955	57	0.880797	0.119203
10	0.894731	0.105269	34	0.729088	0.270912	58	0.574443	0.425557
11	0.73885	0.26115	35	0.329599	0.670401	59	0.276878	0.723122
12	0.779026	0.220974	36	0.613014	0.386986	60	0.785835	0.214165
13	0.574443	0.425557	37	0.562177	0.437823	61	0.759511	0.240489
14	0.465057	0.534943	38	0.670401	0.329599	62	0.5	0.5
15	0.584191	0.415809	39	0.608259	0.391741	63	0.356635	0.643365
16	0.571996	0.428004	40	0.624806	0.375194	64	0.477515	0.522485
17	0.647941	0.352059	41	0.53743	0.46257	65	0.859362	0.140638
18	0.700567	0.299433	42	0.665967	0.334033	66	0.654753	0.345247
19	0.365864	0.634136	43	0.5	0.5	67	0.389361	0.610639
20	0.301535	0.698465	44	0.912136	0.087864	68	0.643365	0.356635
21	0.71095	0.28905	45	0.386986	0.613014	69	0.702661	0.297339
22	0.761333	0.238667	46	0.584191	0.415809	70	0.413382	0.586618
23	0.886954	0.113046	47	0.475021	0.524979	71	0.403717	0.596283
24	0.596283	0.403717	48	0.71095	0.28905	72	0.596283	0.403717

A11: MNL utilities

Choice situation	alt1	alt2	Choice situation	alt1	alt2	Choice situation	alt1	alt2
1	2.24	2.3	25	2.3	1.94	49	2.65	1.94
2	2.49	3	26	1.8	1.25	50	2.74	2.25
3	3.19	2.45	27	1.1	1.44	51	3.15	2.45
4	3	2.49	28	0.99	0.7	52	2.5	1.8
5	1.9	2.49	29	1.74	1.25	53	1.95	2.45
6	3.2	1.59	30	1.9	1.65	54	2.6	1.49
7	2.4	1.99	31	1.4	2.25	55	2.65	2.59
8	2.1	2.69	32	1.99	0.4	56	2.95	3.4
9	0.95	1.25	33	2.59	0.3	57	2.05	0.05
10	2.84	0.7	34	3.44	2.45	58	2.35	2.05
11	1.64	0.6	35	1.64	2.35	59	1.64	2.6
12	2.85	1.59	36	1.95	1.49	60	2.5	1.2
13	3.05	2.75	37	1.45	1.2	61	3.05	1.9
14	1.9	2.04	38	1.8	1.09	62	0.8	0.8
15	1.59	1.25	39	1.54	1.1	63	1.15	1.74
16	1.54	1.25	40	1.85	1.34	64	3.15	3.24
17	2.9	2.29	41	2.2	2.05	65	2.35	0.54

18	2.8	1.95	42	2.34	1.65	66	1.49	0.85
19	1.8	2.35	43	1.35	1.35	67	1.85	2.3
20	0.6	1.44	44	3.14	0.8	68	3.09	2.5
21	3.15	2.25	45	2.29	2.75	69	1.25	0.39
22	2.9	1.74	46	1.59	1.25	70	2.25	2.6
23	3	0.94	47	1.65	1.75	71	1.75	2.14
24	0.79	0.4	48	2.25	1.35	72	1.09	0.7

A12: MNL covariance matrix, Bayesian average

Prior	b1(d0)	b1(d1)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4(d0)	b4(d1)	b5	b
b1(d0)	0.153427	0.085364	-0.0102	-0.01105	-0.00158	0.005049	0.011671	0.016263	0.007116	0.000448
b1(d1)	0.085364	0.184465	-0.03044	-0.03534	-0.00377	0.014425	0.033224	0.041426	0.019292	0.003093
b2(d0)	-0.0102	-0.03044	0.156751	0.087405	-0.00147	-0.00861	-0.01752	-0.03055	-0.01264	-0.00181
b2(d1)	-0.01105	-0.03534	0.087405	0.175346	0.000929	-0.00872	-0.02456	-0.03854	-0.01505	-0.00053
b3(d0)	-0.00158	-0.00377	-0.00147	0.000929	0.145425	0.069967	0.000316	-0.00169	-0.00075	-0.00132
b3(d1)	0.005049	0.014425	-0.00861	-0.00872	0.069967	0.152462	0.009513	0.010323	0.006309	-0.00073
b4(d0)	0.011671	0.033224	-0.01752	-0.02456	0.000316	0.009513	0.255404	0.046074	0.013754	0.035121
b4(d1)	0.016263	0.041426	-0.03055	-0.03854	-0.00169	0.010323	0.046074	0.276748	0.017716	0.035263
b5	0.007116	0.019292	-0.01264	-0.01505	-0.00075	0.006309	0.013754	0.017716	0.009939	0.001698
b	0.000448	0.003093	-0.00181	-0.00053	-0.00132	-0.00073	0.035121	0.035263	0.001698	0.050889

D-efficient Bayesian design used in final surveys
Farmer survey deign

This is the Ngene syntax and design output of D-efficient Bayesian design which was used in the final survey conducted with tomato farmers in Khushab, Pakistan. This design has 10 blocks and 60 rows.

A13: Negene syntax

Design;
alts = Alt1, Alt2,Alt3;
block= 10, minsum, total(3 mins);
rows = 60;
eff = (mnl,d,mean);
model:
U(Alt1) =
b1.dummy[(n,0.61,0.4)] * irr[1,0] +
b2.dummy[(n,0.21,0.32)|(n,-0.022,0.37)] * fer[1,2,0] +
b3.dummy[(n,0.94,0.35)|(n,1.93,0.41)] * pes[1,2,0] +
b4[(n,.2,0.05)] * subs[2,4,6,8,01] /
U(Alt2) = b1.dummy * irr +
b2.dummy * fer + b3.dummy * pes + b4 * subs /
U(Alt3)=b0[(u, 0.41,0.71)]

$					

A14: MNL efficiency measures

		Bayesian				
	Fixed	Mean	Std dev.	Median	Minimum	Maximum
D error	0.080754	0.088014	0.005851	0.087205	0.078184	0.112516
A error	0.1752	0.18933	0.014231	0.187584	0.162559	0.241187
B estimate	41.43964	39.53636	10.47398	38.69357	19.7487	74.06635
S estimate	1350.327	2441.388	15039.93	41.33311	1.409988	188436
Prior	b1(d0)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4
Fixed prior value	0.61	0.21	-0.022	0.94	1.93	0.2
Sp estimates	1.179278	14.35162	1350.327	0.960852	0.386881	0.572814
Sp t-ratios	1.804878	0.517375	0.053338	1.99953	3.151136	2.589699
Sb mean estimates	45.57992	693.7038	1732.568	11.00291	0.477474	0.899411
Sb mean t-ratios	1.736625	0.712948	0.675731	1.901417	2.998724	2.441948

A15: MNL choice probabilities

Choice situation	**alt1**	**alt2**	**Alt3**	**Choice situation**	**alt1**	**alt2**	**alt3**
1	0.759901	0.168206	0.071894	31	0.525228	0.393009	0.081764
2	0.247063	0.700394	0.052544	32	0.162395	0.766651	0.070954
3	0.46594	0.392312	0.141749	33	0.286742	0.29312	0.420138
4	0.766835	0.17317	0.059996	34	0.585171	0.302447	0.112382
5	0.60721	0.336593	0.056198	35	0.514331	0.358837	0.126832
6	0.766651	0.162395	0.070954	36	0.695244	0.186096	0.11866
7	0.545904	0.318125	0.135971	37	0.465533	0.480671	0.053795
8	0.493187	0.423642	0.08317	38	0.701494	0.254987	0.04352
9	0.428652	0.512164	0.059184	39	0.375073	0.571989	0.052938
10	0.657039	0.207627	0.135334	40	0.56971	0.378088	0.052202
11	0.423642	0.493187	0.08317	41	0.574436	0.372929	0.052635
12	0.726149	0.218275	0.055576	42	0.193156	0.773943	0.032901
13	0.29406	0.655752	0.050188	43	0.251791	0.61807	0.130139
14	0.378088	0.56971	0.052202	44	0.471011	0.475745	0.053244
15	0.358837	0.514331	0.126832	45	0.475745	0.471011	0.053244
16	0.292693	0.657947	0.049359	46	0.098761	0.858088	0.043151
17	0.467296	0.440964	0.09174	47	0.322146	0.526896	0.150958
18	0.616025	0.32809	0.055885	48	0.32932	0.275622	0.395057
19	0.228268	0.692647	0.079085	49	0.686993	0.260427	0.052579

20	0.718209	0.225599	0.056191	50	0.26438	0.682243	0.053377
21	0.649024	0.21432	0.136656	51	0.79394	0.156806	0.049255
22	0.226645	0.693246	0.080109	52	0.294861	0.654914	0.050225
23	0.330733	0.517657	0.15161	53	0.291351	0.575092	0.133557
24	0.642018	0.25079	0.107191	54	0.477309	0.431024	0.091667
25	0.422644	0.448779	0.128577	55	0.578761	0.28683	0.134409
26	0.387773	0.529758	0.082469	56	0.146854	0.802267	0.050879
27	0.374741	0.486013	0.139245	57	0.682243	0.26438	0.053377
28	0.630999	0.241605	0.127396	58	0.270043	0.584398	0.145559
29	0.313372	0.549709	0.136919	59	0.529758	0.387773	0.082469
30	0.168206	0.759901	0.071894	60	0.16541	0.763892	0.070699

A16: MNL utilities

Choice situation	alt1	alt2	Alt3	Choice situation	alt1	alt2	alt3
1	2.918	1.41	0.56	31	2.42	2.13	0.56
2	2.108	3.15	0.56	32	1.388	2.94	0.56
3	1.75	1.578	0.56	33	0.178	0.2	0.56
4	3.108	1.62	0.56	34	2.21	1.55	0.56
5	2.94	2.35	0.56	35	1.96	1.6	0.56
6	2.94	1.388	0.56	36	2.328	1.01	0.56
7	1.95	1.41	0.56	37	2.718	2.75	0.56
8	2.34	2.188	0.56	38	3.34	2.328	0.56
9	2.54	2.718	0.56	39	2.518	2.94	0.56
10	2.14	0.988	0.56	40	2.95	2.54	0.56
11	2.188	2.34	0.56	41	2.95	2.518	0.56
12	3.13	1.928	0.56	42	2.33	3.718	0.56
13	2.328	3.13	0.56	43	1.22	2.118	0.56
14	2.54	2.95	0.56	44	2.74	2.75	0.56
15	1.6	1.96	0.56	45	2.75	2.74	0.56
16	2.34	3.15	0.56	46	1.388	3.55	0.56
17	2.188	2.13	0.56	47	1.318	1.81	0.56
18	2.96	2.33	0.56	48	0.378	0.2	0.56
19	1.62	2.73	0.56	49	3.13	2.16	0.56

20	3.108	1.95	0.56	50	2.16	3.108	0.56
21	2.118	1.01	0.56	51	3.34	1.718	0.56
22	1.6	2.718	0.56	52	2.33	3.128	0.56
23	1.34	1.788	0.56	53	1.34	2.02	0.56
24	2.35	1.41	0.56	54	2.21	2.108	0.56
25	1.75	1.81	0.56	55	2.02	1.318	0.56
26	2.108	2.42	0.56	56	1.62	3.318	0.56
27	1.55	1.81	0.56	57	3.108	2.16	0.56
28	2.16	1.2	0.56	58	1.178	1.95	0.56
29	1.388	1.95	0.56	59	2.42	2.108	0.56
30	1.41	2.918	0.56	60	1.41	2.94	0.56

A17: MNL covariance matrix, Bayesian average

Prior	b1(d0)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4	b0
b1(d0)	0.114226	0.00876	-0.00289	0.043861	0.091835	0.010226	0.139637
b2(d0)	0.00876	0.164751	0.079526	0.013802	0.030835	0.003317	0.108445
b2(d1)	-0.00289	0.079526	0.170127	-0.00255	-0.00415	-0.00054	0.075925
b3(d0)	0.043861	0.013802	-0.00255	0.221004	0.194275	0.015763	0.21974
b3(d1)	0.091835	0.030835	-0.00415	0.194275	0.375129	0.032011	0.35652
b4	0.010226	0.003317	-0.00054	0.015763	0.032011	0.005964	0.044637
b0	0.139637	0.108445	0.075925	0.21974	0.35652	0.044637	0.688504

A18: MNL fisher matrix

Prior	b1(d0)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4	b0
b1(d0)	12.26512	0.591528	0.971504	1.090412	-1.48929	1.534242	-2.36411
b2(d0)	0.591528	8.493563	-3.2696	0.628027	-0.14582	4.340338	-1.50354
b2(d1)	0.971504	-3.2696	8.21257	0.533696	0.746912	7.863762	-1.6546
b3(d0)	1.090412	0.628027	0.533696	8.899802	-4.07263	8.696029	-1.67424
b3(d1)	-1.48929	-0.14582	0.746912	-4.07263	8.209705	-20.0539	-1.40856
b4	1.534242	4.340338	7.863762	8.696029	-20.0539	398.159	-20.0664
b0	-2.36411	-1.50354	-1.6546	-1.67424	-1.40856	-20.0664	4.915838

<u>Consumer survey deign</u>

This is Ngene code of D-efficient Bayesian design which was used in the final survey conducted with tomato consumers in Islamabad, Pakistan. This design has 12 blocks and 72 rows.

A19: Negene syntax

Design;						
alts = Alt1, Alt2,Alt3;						

block= 12, minsum, total(3 mins);						
rows = 72;						
eff = (mnl,d,mean);						
model:						
U(Alt1) =						
b1.dummy[(n,1.43,0.43)|(n,1.67,0.47)] * irr[1,2,0] +						
b2.dummy[(n,0.72,0.4)|(n,0.66,0.41)] * fer[1,2,0] +						
b3.dummy[(n,0.84,0.43)|(n,0.93,0.4)] * pes[1,2,0] +						
b4.dummy[(n,0.54,0.49)|(n,0.75,0.37)] * ins[1,2,0] +						
b5[(u,-.01,0.08)] * price[10,15,20,25,30] /						
U(Alt2) = b1.dummy * irr +						
b2.dummy * fer + b3.dummy * pes + b.dummy4 * ins + b5 * price /						
U(Alt3)=b0[(n, 0.05,0.78)]						
$						

A20: MNL efficiency measures

		Bayesian								
	Fixed	Mean	Std dev.	Median	Minimum	Maximum				
D error	0.070292	0.081826	0.005428	0.081725	0.069516	0.100044				
A error	0.189704	0.218082	0.019879	0.217225	0.172297	0.275526				
B estimate	16.31321	18.17388	13.71707	14.11301	0.911672	71.50287				
S estimate	2.942038	15828.92	174600.7	31.22591	1.698408	2403841				
Prior	b1(d0)	b1(d1)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4(d0)	b4(d1)	b5	b
Fixed prior value	1.43	1.67	0.72	0.66	0.84	0.93	0.54	0.75	0.035	0
Sp estimates	0.551683	0.498866	1.279822	1.462786	1.02609	0.906852	2.942038	1.644704	1.327837	Undefined
Sp t-ratios	2.638829	2.775007	1.732532	1.620562	1.934921	2.058201	1.142699	1.528313	1.700919	0
Sb mean estimates	0.93973	0.72414	21.0772	168.1885	3098.351	16.20821	12267.75	196.3697	91.16103	Undefined
Sb mean t-ratios	2.45109	2.58804	1.596972	1.506938	1.747105	1.876067	1.134457	1.389433	1.554827	0

A21: MNL covariance matrix

Prior	b1(d0)	b1(d1)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4(d0)	b4(d1)	b5	b	b0
b1(d0)	0.293663	0.265501	0.10044	0.093295	0.117508	0.134896	0.06095	0.089731	0.005126	0.009014	0.412968
b1(d1)	0.265501	0.362163	0.121116	0.113068	0.140135	0.159116	0.076456	0.10433	0.006085	0.010215	0.479623

b2(d0)	0.10044	0.121116	0.172704	0.102515	0.057936	0.066923	0.032883	0.040922	0.002547	0.004099	0.243263
b2(d1)	0.093295	0.113068	0.102515	0.165866	0.055624	0.063065	0.03126	0.036445	0.002436	0.003917	0.233677
b3(d0)	0.117508	0.140135	0.057936	0.055624	0.188466	0.129791	0.035184	0.054872	0.002951	0.0061	0.276047
b3(d1)	0.134896	0.159116	0.066923	0.063065	0.129791	0.204169	0.034904	0.058883	0.003384	0.005507	0.303263
b4(d0)	0.06095	0.076456	0.032883	0.03126	0.035184	0.034904	0.223318	0.044311	0.001487	0.030759	0.170664
b4(d1)	0.089731	0.10433	0.040922	0.036445	0.054872	0.058883	0.044311	0.240823	0.002178	0.03353	0.21163
b5	0.005126	0.006085	0.002547	0.002436	0.002951	0.003384	0.001487	0.002178	0.000423	0.000174	0.015303
b	0.009014	0.010215	0.004099	0.003917	0.0061	0.005507	0.030759	0.03353	0.000174	0.045441	0.048254
b0	0.412968	0.479623	0.243263	0.233677	0.276047	0.303263	0.170664	0.21163	0.015303	0.048254	1.436941

A22: MNL fisher matrix

Prior	b1(d0)	b1(d1)	b2(d0)	b2(d1)	b3(d0)	b3(d1)	b4(d0)	b4(d1)	b5	b	b0
b1(d0)	10.79559	-6.30213	-0.36148	-0.17049	-0.28122	-0.80769	-0.04043	-0.44545	-5.74802	0.440159	-0.56881
b1(d1)	-6.30213	10.12127	-0.95159	-0.75824	-0.88974	-1.28772	-0.65055	-0.64171	-19.6784	0.910232	-0.48922
b2(d0)	-0.36148	-0.95159	10.25144	-4.67996	0.079138	-0.19239	-0.05199	-0.0434	5.956478	0.451741	-0.59356
b2(d1)	-0.17049	-0.75824	-4.67996	10.39673	-0.07313	-0.09867	-0.05187	0.132529	5.132729	0.350636	-0.64128
b3(d0)	-0.28122	-0.88974	0.079138	-0.07313	10.33813	-4.78893	-0.05203	-0.227	6.774448	0.305899	-0.64185
b3(d1)	-0.80769	-1.28772	-0.19239	-0.09867	-4.78893	10.44454	0.253133	-0.13657	1.909236	0.43159	-0.61853
b4(d0)	-0.04043	-0.65055	-0.05199	-0.05187	-0.05203	0.253133	5.385917	0	5.146088	-3.11435	-0.38733
b4(d1)	-0.44545	-0.64171	-0.0434	0.132529	-0.227	-0.13657	0	5.387638	0.893359	-3.40058	-0.28836
b5	-5.74802	-19.6784	5.956478	5.132729	6.774448	1.909236	5.146088	0.893359	3970.384	25.78465	-39.218
b	0.440159	0.910232	0.451741	0.350636	0.305899	0.43159	-3.11435	-3.40058	25.78465	27.16289	-1.0297
b0	-0.56881	-0.48922	-0.59356	-0.64128	-0.64185	-0.61853	-0.38733	-0.28836	-39.218	-1.0297	2.022

A23: MNL choice probabilities

Choice situation	alt1	alt2	Alt3	Choice situation	alt1	alt2	alt3
1	0.733595	0.251629	0.014775	37	0.685176	0.292854	0.02197
2	0.485305	0.495109	0.019585	38	0.541477	0.346992	0.111531
3	0.591764	0.355352	0.052884	39	0.619223	0.353706	0.027071
4	0.786584	0.193969	0.019447	40	0.299802	0.687542	0.012656
5	0.773163	0.206539	0.020297	41	0.600544	0.375341	0.024115
6	0.795834	0.194297	0.009869	42	0.615017	0.369315	0.015668
7	0.761371	0.227039	0.01159	43	0.412026	0.539739	0.048235
8	0.662943	0.319478	0.017579	44	0.638223	0.33653	0.025247
9	0.75803	0.221566	0.020404	45	0.831446	0.151891	0.016663
10	0.748229	0.232226	0.019545	46	0.396146	0.579278	0.024576
11	0.687128	0.263096	0.049775	47	0.612883	0.339738	0.047379
12	0.846502	0.144187	0.00931	48	0.37947	0.60715	0.01338
13	0.625213	0.350056	0.024732	49	0.497708	0.409532	0.09276
14	0.504294	0.442819	0.052887	50	0.66598	0.293319	0.040701
15	0.581627	0.40175	0.016624	51	0.575939	0.333954	0.090107
16	0.690212	0.286288	0.0235	52	0.391611	0.584215	0.024174
17	0.493907	0.465144	0.04095	53	0.524111	0.46022	0.015669
18	0.852856	0.131445	0.015699	54	0.461461	0.499895	0.038644
19	0.794441	0.188225	0.017333	55	0.62376	0.349242	0.026998

20	0.629609	0.359639	0.010752	56	0.55041	0.411852	0.037738
21	0.555263	0.432439	0.012298	57	0.322516	0.662587	0.014897
22	0.669811	0.319576	0.010612	58	0.311564	0.608869	0.079567
23	0.394853	0.589052	0.016095	59	0.815655	0.145328	0.039017
24	0.737607	0.255548	0.006844	60	0.384008	0.57863	0.037362
25	0.620877	0.361815	0.017307	61	0.392208	0.590985	0.016807
26	0.491603	0.496543	0.011854	62	0.546273	0.417014	0.036713
27	0.512551	0.463775	0.023675	63	0.406615	0.509213	0.084172
28	0.405223	0.552492	0.042285	64	0.681687	0.300237	0.018076
29	0.733916	0.251739	0.014345	65	0.327794	0.653528	0.018679
30	0.347889	0.640266	0.011845	66	0.445496	0.538716	0.015787
31	0.370742	0.593186	0.036072	67	0.533911	0.450442	0.015646
32	0.830517	0.151722	0.017762	68	0.823295	0.159703	0.017002
33	0.464093	0.422034	0.113873	69	0.485187	0.47558	0.039234
34	0.475491	0.49987	0.024639	70	0.422345	0.558818	0.018837
35	0.71187	0.278076	0.010053	71	0.500183	0.461727	0.038091
36	0.458802	0.522496	0.018702	72	0.668277	0.309421	0.022303

A24: MNL utilities

Choice situation	alt1	alt2	Alt3	Choice situation	alt1	alt2	alt3
1	3.955	2.885	0.05	37	3.49	2.64	0.05
2	3.26	3.28	0.05	38	1.63	1.185	0.05
3	2.465	1.955	0.05	39	3.18	2.62	0.05
4	3.75	2.35	0.05	40	3.215	4.045	0.05
5	3.69	2.37	0.05	41	3.265	2.795	0.05
6	4.44	3.03	0.05	42	3.72	3.21	0.05
7	4.235	3.025	0.05	43	2.195	2.465	0.05
8	3.68	2.95	0.05	44	3.28	2.64	0.05
9	3.665	2.435	0.05	45	3.96	2.26	0.05
10	3.695	2.525	0.05	46	2.83	3.21	0.05
11	2.675	1.715	0.05	47	2.61	2.02	0.05
12	4.56	2.79	0.05	48	3.395	3.865	0.05
13	3.28	2.7	0.05	49	1.73	1.535	0.05
14	2.305	2.175	0.05	50	2.845	2.025	0.05
15	3.605	3.235	0.05	51	1.905	1.36	0.05
16	3.43	2.55	0.05	52	2.835	3.235	0.05
17	2.54	2.48	0.05	53	3.56	3.43	0.05
18	4.045	2.175	0.05	54	2.53	2.61	0.05

19	3.875	2.435	0.05	55	3.19	2.61	0.05
20	4.12	3.56	0.05	56	2.73	2.44	0.05
21	3.86	3.61	0.05	57	3.125	3.845	0.05
22	4.195	3.455	0.05	58	1.415	2.085	0.05
23	3.25	3.65	0.05	59	3.09	1.365	0.05
24	4.73	3.67	0.05	60	2.38	2.79	0.05
25	3.63	3.09	0.05	61	3.2	3.61	0.05
26	3.775	3.785	0.05	62	2.75	2.48	0.05
27	3.125	3.025	0.05	63	1.625	1.85	0.05
28	2.31	2.62	0.05	64	3.68	2.86	0.05
29	3.985	2.915	0.05	65	2.915	3.605	0.05
30	3.43	4.04	0.05	66	3.39	3.58	0.05
31	2.38	2.85	0.05	67	3.58	3.41	0.05
32	3.895	2.195	0.05	68	3.93	2.29	0.05
33	1.455	1.36	0.05	69	2.565	2.545	0.05
34	3.01	3.06	0.05	70	3.16	3.44	0.05
35	4.31	3.37	0.05	71	2.625	2.545	0.05
36	3.25	3.38	0.05	72	3.45	2.68	0.05

A25: Example of the design output used to create the choice sets

This is an example of design output (only four blocks of code) from Ngene software that produces a spreadsheet of code which is used to make the choice situations using excel formula. All designs had similar output.

Choice situation	alt1.x1	alt1.x2	alt1.x3	alt1.x4	alt1.x5	alt2.x1	alt2.x2	alt2.x3	alt2.x4	alt2.x5	Block
1	2	0	2	0	4	0	1	0	1	5	1
2	0	2	0	2	5	1	0	1	0	0	1
3	1	0	0	1	3	2	1	1	2	4	1
4	1	2	2	1	0	2	0	0	2	1	1
5	0	1	1	0	0	1	2	2	1	1	1
6	1	2	2	1	1	2	0	0	2	2	1
7	2	2	0	0	1	0	0	1	1	2	2
8	1	0	1	0	3	2	1	2	1	4	2
9	2	1	2	1	1	0	2	0	2	2	2
10	1	2	1	2	2	2	0	2	0	3	2
11	2	1	1	2	1	0	2	2	0	2	2
12	2	0	0	2	2	0	1	1	0	3	2
13	2	2	1	1	2	0	0	2	2	3	3
14	1	1	0	0	0	2	2	1	1	1	3
15	1	2	1	2	0	2	0	2	0	1	3
16	2	0	0	2	4	0	1	1	0	5	3
17	0	1	0	1	3	1	2	1	2	4	3
18	1	2	2	1	4	2	0	0	2	5	3
19	0	0	2	2	2	1	1	0	0	3	4
20	0	0	1	1	1	1	1	2	2	2	4
21	1	0	1	0	5	2	1	2	1	0	4
22	2	1	1	2	5	0	2	2	0	0	4
23	0	1	0	1	5	1	2	1	2	0	4
24	0	0	2	2	1	1	1	0	0	2	4

Appendix – B

Appendix – II presents the results of pilot surveys. Two pilot surveys were conducted to collect the priors to create the experimental designs used in final surveys. Furthermore, pilots were also used to test the survey instruments. First pilot survey was designed using orthogonal design, whereas second pilot survey was created using D-efficient Bayesian design. Both pilot surveys involved the complete interviews of farmers and consumers using the actual survey instruments in study areas.

B1 Results of 1st pilot of farmer survey

Conditional logit estimates

Attributes	**Coefficients**
Status-quo	0.536
	(0.435)
Furrow irrigation	0.254
	(0.310)
Drip irrigation	0.538*
	(0.300)
33% less fertilisers	-0.107
	(0.308)
50% less fertilisers	0.129
	(0.292)
25% less pesticides	-0.0551
	(0.296)
33% less pesticides	-0.0153
	(0.303)
2 times inspection	0.0812
	(0.309)
4 times inspection	0.236
	(0.302)
Price premium	-0.0472
	(0.0399)
Pseudo R2	0.035
Observations	432
N	24

B2 Results of 1st pilot of consumer survey

Conditional logit estimates

Attributes	**Coefficients**

Status-quo	-17.98
	(832.8)
Furrow irrigation	0.397
	(0.251)
Drip irrigation	0.186
	(0.251)
33% less fertilisers	0.451*
	(0.256)
50% less fertilisers	0.192
	(0.251)
25% less pesticides	-0.0196
	(0.249)
33% less pesticides	0.153
	(0.263)
2 times inspection	-0.0376
	(0.254)
4 times inspection	-0.333
	(0.259)
Price premium	-0.116***
	(0.0429)
Pseudo R2	0.42
Observations	432
N	24

B3 Results of 2nd pilot of farmer survey

Conditional logit estimates

Attributes	Coefficients
Status-quo	0.414
	(0.650)
Furrow irrigation	0.612**
	(0.307)
Drip irrigation	0.147
	(0.309)
33% less fertilisers	0.209
	(0.300)
50% less fertilisers	-0.0215
	(0.308)
25% less pesticides	0.947***
	(0.299)
33% less pesticides	1.932***
	(0.331)
2 times inspection	0.167
	(0.311)
4 times inspection	0.274
	(0.294)
Price premium	0.0957
	(0.0597)
Pseudo R2	0.32
Observations	432
N	24

B4 Results of 2nd pilot of consumer survey

Conditional logit estimates

Attributes	Coefficients
Status-quo	-1.601***
	(0.503)
Furrow irrigation	0.530*
	(0.271)
Drip irrigation	0.931***
	(0.284)
33% less fertilisers	0.356
	(0.263)
50% less fertilisers	0.222
	(0.262)
25% less pesticides	0.384
	(0.266)
33% less pesticides	0.212
	(0.274)
2 times inspection	0.423
	(0.317)
4 times inspection	0.049
	(0.241)
Price premium	-0.038**
	(0.016)
Pseudo R2	0.28
Observations	432
N	24

Appendix – C Choice cards

Appendix – III presents the model choice cards with visual aid which were used to create the actual choice cards as per the experimental design in both pilots as well as final surveys administered with farmers and consumers in study areas. A9 is an example of the choice cards used for farmer surveys and A10 is an example of consumer surveys choice cards.

C1: Farmer survey choice card

Attributes	Status Quo	Medium level changes	Advance level changes
Irrigation water saving	Flood (No water saving) 	Furrow (70% water saving) 	Drip (70% water saving) 
Fertilisers related water pollution	Unrestricted use 	33% reduction 	50% reduction 
Pesticides use	Unrestricted use 	25% reduction 	33% reduction 
Extra price/kg	Rs. 00	Rs. 2 Rs. 4 Rs. 6	Rs. 8 Rs. 10

C2: Consumer survey choice card

Attributes	Status Quo	Medium level changes	Advance level changes
Irrigation water saving	Flood (No water saving) 	Furrow (50% water saving) 	Drip (70% water saving) 
Fertilisers related water pollution	Unrestricted use 	33% reduction 	50% reduction 
Pesticides use	Unrestricted use 	25% reduction 	33% reduction 
Inspection for labelling	No inspection	Twice/crop season 	Four times/crop season 
Extra price/kg	Rs. 00	Rs.10 Rs.15 Rs. 20	Rs. 25 Rs. 30

Appendix – D Survey questionnaires

Appendix – IV shows the questionnaire used to gather the data from farmers and consumers in study areas. The data collected through questionnaires were mainly used in carrying out the analysis for Chapter 4 of this thesis. However, this data is also used in creating the attribute interactions used in DCE analysis in Chapter 5 and Chapter 6.

D1: Farmer Survey Questionnaire

Village/district: _____________Date:___________ Enumerator name: ________________________

1. Farm decision maker (FDM) is _____ (1= owner, 2= tenant, 3= both)
2. FDM gender ___________ (1=male, 0=female)
3. FDM age (yrs) ________
4. FDM education (years of schooling) ___________
5. Household maximum education (years of schooling) ___________
6. Household size _____________
7. FDM farming experience (years) ____________
8. Distance to the nearest market (km) ______________
9. Household ***on-farm*** average net seasonal income (PKRs) 1= 0 - 100,000 2=100,000 - 200,000, 3= 200,00 – 400,000, 4= 400000+ ________
10. Household ***off-farm*** average monthly income (PKRs) 1= nil, 2=<50000, 3= 50 – 100000, 4= 100000+
11. ***Fulltime*** household members working on-farm _____________off-farm _____________
12. Total cultivable land (acres) _____ grains______ vegetables ________ tomato________others _____
13. Tomato yield/per crop cycle (mounds) *Rabi*: _________ *Kharif:*________
14. Average farm gate price of tomato/mound _________ minimum_________ maximum ________
15. Tomato irrigation water sources 1= canal, 2= tube-well, 3= 1&2, 4=rain, 5=other _____________
16. What type(s) of tomato irrigation is currently used 1= flood, 2= furrow, 3= drip, 4= other __________
17. Have you received any training/advice from your local agriculture extension regarding the application of fertiliser ______ and pesticides______ 1= yes, 0= no
18. Whose advise do you follow when applying pesticide(s) to your tomato crop: 1= extension office, 2= producer (bottle information), 3= pesticides dealer, 4= other _________
19. How do you implement the recommendation 1= exactly, 2= as a guideline (more_____ less _____)
20. Please name the pesticides that you apply to your tomato crop:
    1___________________2________________3__________________4 ___________________
21. Per acre use of pesticides (litres/grams/water dilution)

1___________________2________________3__________________4 ___________________

22. No. of times you experienced a major tomato crop pest or weed outbreak in last 5 years ________
23. What would be the approximate decline in yield/acre (mound) ________ and average fruit size (%) of tomato ________if all pesticides are reduced by 33%?
24. What would be the approximate decline in yield/acre (mound) ________ and average fruit size (%) of tomato ________if no pesticides are applied?
25. What tomato price reduction (Rs/mound) do you expect if pesticides use is reduced by 33% ______
26. How do the pesticides applied to your tomatoes effect your health 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
27. How do the pesticides applied to your tomatoes effect the environment 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
28. Per acre use (kg) of urea _______DAP ________nitrophosphate _______ other ________ for tomato
29. Total manure (dung/gobar) you use in tomato crop (mounds) __________
30. Whose advise do you follow when it comes to applying fertilisers to your tomato crop: 1= extension office, 2= producer (bag information), 3= shopkeeper, 4= other _________
31. How do you implement the recommendation 1= exactly, 2= as a guideline (more_____ less _____)
32. What would be the approximate decline in tomato yield/acre (mound) ________ and average fruit size (%) of tomato ________if all fertilisers are reduced by 33%
33. What would be the approximate decline in tomato yield/acre (mound) ________ and average fruit size (%) of tomato ________if no fertilisers are applied
34. What tomato price reduction (Rs/mound) do you expect if fertilisers use is reduced by 33% ______
35. How do the fertilisers applied to your tomatoes effect your health 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
36. How do the fertlisers applied to your tomatoes effect the environment 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
37. What is the importance of preserving the environment 1 = not important, 2 = somewhat important, 3= important, 4= highly important, 5 = do not know
38. Assume there are only two tomato varieties with price 1.) Rs. 20/kg and 2) Rs. 40/kg. The tomato variety with the lower price has 10% risk of disease and the one with the higher price has 50% disease risk. Which one you would you grow? 1= Rs. 20/kg, 2=Rs. 40/kg.
39. What is your preference for irrigation 1= furrow irrigation, 2= drip irrigation
40. Could you please tell us the reason for this choice ____?
41. What is your preference for pesticide reduction 1= medium reduction, 2= higher reduction
42. Could you please tell us the reason for this choice ____?

43. What is your preference for fertiliser reduction 1= medium reduction, 2= higher reduction
44. Could you please tell us the reason for this choice ____?

D2: Consumer Survey Questionnaire

Location: _____________Date: _____________Enumerator name: ___________________________

45. Shoping decision maker age (years) ____________
46. Shoping decision maker gender ____________ (1=male, 0=female)
47. Shoping decision maker education (years of schooling) ___________
48. Household maximum education (years of schooling) ___________
49. Household size ___________adults ________ cildren_______
50. Household average monthly income (PKRs) 1= 100,000 – 150,000, 2= 150,000 – 200,000, 3= 200000 – 300000, 4 = 300000 – 400000, 5= 400,000+ _____________
51. Average consumption of tomato per week (kg)___________
52. Are you aware that considerable amounts of fertilisers and pesticides are used in growing tomatoes? 1= yes, 0= no
53. How do the pesticides applied to the vegetables you eat affect your health 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
54. How do the pesticides applied to the vegetables you eat affect the environment 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
55. How do the fertilisers applied to the vegetables you eat affect your health 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
56. How do the fertilisers applied to the vegetables you eat affect the environment 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
57. Could you please explain the meaning of an 'organic vegetable'? 1= yes, 0= no
58. How would consuming organic vegetables impact your health? 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
59. How would consuming organic vegetables impact the environment? 1=very positively, 2= positively 3=negatively, 4= very negatively, 5=no difference, 6= don't know
60. Would you be more likely to purchase organic vegetables if they are certified by 1= government, 2= private company, 3= international organization
61. Rank the importance of the following factors in your tomato purchase decision (1 being most important) location____,size____,colour____,freshness___,chemical free___, carbon footprint ____

62. What is the importance of preserving the environment 1 = not important, 2 = somewhat important, 3= important, 4= highly important, 5 = do not know
63. How would you assess the current state of your health 1= bad, 2= poor, 3= alright, 4= good, 5= very good
64. Do you consider yourself to be health conscious 1= yes, 2 = no, 3= somewhat health conscious
65. You read the ingredients/nutrition facts on food labels 1=quiet often, 2=rarely, 3=never
66. How many times in the last year did you come across any news related to food contamination? _______
67. How many times a month do you exercise? _________
68. What would your willingness to pay an additional price/kg for tomatoes with the proposed reductions? _________

Appendix –E Models with correlation

E1: Model in preference-space for farmer data with correlated coefficients

Base model			
Attribute	*Parameter*	*Estimate*	*St. error*
Status-quo	Mean of coeff.	-12.854	3.314
	St. dev. of coeff.	12.955	2.769
Drip irrigation	Mean of coeff.	-3.238	0.414
	St. dev. of coeff.	2.997	0.403
33% less fertilisers	Mean of coeff.	0.405	0.158
	St. dev. of coeff.	0.323	0.320
50% less fertilisers	Mean of coeff.	0.470	0.169
	St. dev. of coeff.	0.586	0.432
Fertilisers correlation	***Between 33% and 50%***	***0.993***	***0.046***
25% less pesticides	Mean of coeff.	0.238	0.184
	St. dev. of coeff.	0.929	0.383
33% less pesticides	Mean of coeff.	0.625	0.190
	St. dev. of coeff.	0.996	0.326
Pesticides correlation	***Between 25% and 33%***	***0.831***	***0.180***
Price premium	Mean of coeff.	0.122	0.026
Log likelihood	-715.87	-	-
No. of parameters	15	-	-
Observation	4514	-	-
N	251	-	-

E2: Model in preference-space for farmer data with with full correlation matrix

	Estimate	St. error
Status quo	-13.393	2.834
Drip irrigation	-3.562	0.479
33% less fertilisers	0.432	0.293
50% less fertilisers	0.218	0.286
25% less pesticides	0.093	0.327
33% less pesticides	0.429	0.280
Price premium	0.134	0.029
Log likelihood	-707.47	
No. of parameters	28	
Observation	4518	
N	251	

E3: Parameters of Cholesky decomposition of covariance matrix for E2

	StatQuo	Irrig:Drip	Fert:-33	Fert:-50	Fert:-25	Fert:-33
Status quo	3.349 (0.43)					
Drip irrigation	-0.090 (0.33)	0.749 (0.26)				
33% less fertilisers	0.322 (0.35)	0.998 (0.31)	-0.018 (0.28)			
50% less fertilisers	0.264 (0.40)	-0.459 (0.41)	0.210 (0.45)	1.106 (0.36)		
25% less pesticides	0.277 (0.34)	0.346 (0.39)	0.538 (0.37)	1.149 (0.37)	0.160 (0.20)	
33% less pesticides	1.770 (0.58)	-7.902 (1.57)	9.364 (1.95)	-5.229 (1.39)	-5.904 (1.19)	0.300 (0.46)

E4: Model in preference-space for consumer data with correlated coefficients

Model with correlated coefficients		
Parameter	*Estimate*	*St. error*
Status quo	-1.832	0.430
Furrow irrigation	0.465	0.165
Drip irrigation	0.768	0.177
33% less fertilisers	0.636	0.139
50% less fertilisers	0.757	0.144
25% less pesticides	0.246	0.131
33% less pesticides	0.410	0.144
2 times inspection	0.983	0.160
4 times inspection	1.059	0.175
Price premium	-0.061	0.009
Log likelihood	-1224.16	
No. of parameters	55	
Observation	4,482	
N	249	

E5: Parameters of Cholesky decomposition of correlation matrix between coefficients for E4

	SQ	Irrig:F	Irrig:D	Fert:-33	Fert:-50	Pest:-25	Pest:-33	Insp:2	Insp:4

Status quo	3.607 (3.61)	0	0	0	0	0	0	0	0
Furrow irrigation	0.486 (0.49)	0.861 (0.86)	0	0	0	0	0	0	0
Drip irrigation	0.406 (0.41)	0.630 (0.63)	0.784 (0.78)	0	0	0	0	0	0
33% less fertilisers	0.507 (0.51)	0.047 (0.05)	0.412 (0.41)	-0.338 -(0.34)	0	0	0	0	0
50% less fertilisers	0.550 (0.55)	-0.354 -(0.35)	0.570 (0.57)	-0.492 -(0.49)	-0.158 -(0.16)	0	0	0	0
25% less pesticides	0.378 (0.38)	-0.215 -(0.22)	-0.398 -(0.40)	-0.407 -(0.41)	-0.065 -(0.06)	0.168 (0.17)	0	0	0
33% less pesticides	0.496 (0.50)	-0.017 -(0.02)	-0.120 -(0.12)	-0.667 -(0.67)	-0.104 -(0.10)	0.214 (0.21)	0.028 (0.03)	0	0
2 times inspection	0.308 (0.31)	0.049 (0.05)	-0.612 -(0.61)	0.667 (0.67)	0.326 (0.33)	-0.217 -(0.22)	-0.305 -(0.31)	-0.068 -(0.07)	0
4 times inspection	0.187 (0.19)	0.098 (0.10)	-0.737 -(0.74)	0.222 (0.22)	0.734 (0.73)	0.004 (0.00)	-0.429 -(0.43)	-0.236 -(0.24)	-0.008 -(0.01)

Appendix –F Attribute interactions backward search process

F1: Initial model in preference-space for farmer data with all the attribute interactions

***********Mixed logit- all normally distributed coefficients except price and interaction terms***
mixlogit y sqinc ir1inc fe1inc fe2inc pe1inc pe2inc priinc sqedu ir1edu fe1edu fe2edu pe1edu pe2edu priedu sqage ir1age fe1age fe2age pe1age pe2age priage sqpri ir1pri fe1pri fe2pri pe1pri pe2pri sqhhsize ir1hhsize fe1hhsize fe2hhsize pe1hhsize pe2hhsize prihhsize sqfarmexp ir1farmexp fe1farmexp fe2farmexp pe1farmexp pe2farmexp prifarmexp, rand($rhsw) group(csetid) id(consid) nrep(1000) difficult iterate(200)

F2: Initial model in preference-space for consumer data with all the attribute interactions

***********Mixed logit- all normally distributed coefficients except price and interaction terms***
mixlogit y sqinc ir1inc fe1inc fe2inc pe1inc pe2inc priinc sqedu ir1edu fe1edu fe2edu pe1edu pe2edu priedu sqage ir1age fe1age fe2age pe1age pe2age priage sqpri ir1pri fe1pri fe2pri pe1pri pe2pri sqhhsize ir1hhsize fe1hhsize fe2hhsize pe1hhsize pe2hhsize prihhsize sqfarmexp ir1farmexp fe1farmexp fe2farmexp pe1farmexp pe2farmexp prifarmexp, rand($rhsw) group(csetid) id(consid) nrep(1000) difficult iterate(200)

Appendix – G Do files of Stata routines used in data analysis

Appendix – V presents the Stata do-files used in conducting the data analysis for this research. A13 shows the Stata routines used in Chapter 4. This includes Stata routines used to conduct analysis of farmer data and consumer data with regards to their perceptions of different farming practices. A14 and A15 however show the Stata routines used in Chapter 5 and 6 to conduct the DCE analysis of farmer preferences and willingness to accept to adopt the proposed changes in current agricultural practices, and consumer preferences and consumer preferences and willingness to pay for relatively cleaner food.

G1: Stata routines for farmer data estimates used in Chapter 4

```
clear all
set more off
*log close
cd "E:\PhD research\Thesis\Project 1 & 2\Non DCE consumer & farmer\Farmer survey"
import excel "Remaining farmer survey data.xlsx", sheet("Sheet1") firstrow
*use consumer.dta, clear
*open log
*log using ajaz_consumer, replace
label variable questionnaire "Questionnaire serial no"
label variable ownership "Ownership status 1=owner, 2=tanent, 3=both (Ownership+lease)"
label variable gender "Farm decision maker gender"
label variable age "Farm decision maker age"
label variable edu "Farm decision maker education"
label variable maxedu "Household maximum education"
label variable hhsize "Total household size"
label variable farmexp "Farm decision maker farming experience"
label variable mktdist "Distance to nearest market"
label variable farminc "Household on-farm average net seasonal income"
label variable offarminc "Household off-farm monthly income"
label variable totalinc "Household total income"
label variable onfarmw "Household members working on-farm"
label variable offarmw "Household members working off-farm"
label variable totland "Total cultivable land (acres)"
label variable grainland "Cultivable land for grains (acres)"
label variable vegland "Cultivable land for vegetables (acres)"
label variable tomland "Cultivable land for other tomato (acres)"
label variable otherland "Cultivable land for other crops (acres)"
label variable tomyield "Tomato yield/per crop cycle (mounds)"
label variable avprice "Average farm gate price of tomato/mound"
label variable minprice "Minimum farm gate price of tomato/mound"
label variable maxprice "Maximum farm gate price of tomato/mound"
label variable irrsources "Tomato irrigation sources"
label variable irrtypes "Irrigation types"
label variable trfertapp "Training/advice for fertiliser application"
label variable trpestapp "Training/advice for pesticides application"
label variable pestappadv "Whose advise do you follow when applying pesticide(s)"
label variable recimpp "How do you implement the recommendation"
label variable pest1 "Per acre use of pesticide 1 (potterton c) ml"
```

label variable water1 "Water (ltrs) to dilute pesticide 1"
label variable pest2 "Per acre use of pesticide 2 (kava karan) ml"
label variable water2 "Water (ltrs) to dilute pesticide 2"
label variable pest3 "Per acre use of pesticide 3 (grow up)(gm)"
label variable water3 "Water (ltrs) to dilute pesticide 3"
label variable pest4 "Per acre use of pesticide 4 (timer) gm"
label variable water4 "Water (ltrs) to dilute pesticide 4"
label variable pest5 "Per acre use of pesticide 5 (lambda) ml"
label variable water5 "Water (ltrs) to dilute pesticide 5"
label variable pest6 "Per acre use of pesticide 6 (escore) gm"
label variable water6 "Water (ltrs) to dilute pesticide 6"
label variable poutbrk "No. of times you experienced a major tomato crop pest or weed outbreak in last 5 years"
label variable yld33p "Approximate decline in yield/acre (%) if all pesticides are reduced by 33%"
label variable size33p "Approximate decline in average size (%) if all pesticides are reduced by 33%"
label variable yld100p "Approximate decline in yield/acre (%) if no pesticides are applied"
label variable size100p "Approximate decline in average size (%) if no pesticides are applied"
label variable price33p "Price reduction (Rs/mound) if pesticides use is reduced by 33%"
label variable pimpacth "Pesticides applied to tomatoes affect on health"
label variable pimpacte "Pesticides applied to tomatoes affect on environment"
label variable urea "Per acre use (kg) of urea for tomato crop"
label variable dap "Per acre use (kg) of DAP for tomato crop"
label variable nitroph "Per acre use (kg) of nitrophosphate for tomato crop"
label variable potash "Per acre use (kg) of potash for tomato crop"
label variable amunnit "Per acre use (kg) of ammunium nitrate for tomato crop"
label variable manure "Total manure you use in tomato crop (tons)"
label variable fertappadv "Whose advise do you follow when applying fertiliser(s)"
label variable recimpf "How do you implement the recommendation"
label variable yld33f "Approximate decline in tomato yield/acre (%) if all fertilisers are reduced by 33%"
label variable size33f "Approximate decline in tomato average size (%) if all fertilisers are reduced by 33%"
label variable yld100f "Approximate decline in tomato yield/acre (%) if no fertilisers are applied"
label variable size100f "Approximate decline in average tomato size (%) if no fertilisers are applied"
label variable price33f "Tomato price reduction (Rs/mound) if fertilisers use is reduced by 33%"
label variable fimpacth "Fertilisers applied to tomatoes affect on health"
label variable fimpacte "Fertilisers applied to tomatoes affect on environment"
label variable imppreenv "Importance of preserving the environment"
label variable varieties "Choice of tomato varieties"
label variable irripref "What is your preference for irrigation"
label variable irrireason "Reason for this irrigation choice"
label variable pestpref "What is your preference for pesticide reduction"
label variable pestreason "Reason for this pesticides choice"
label variable fertpref "What is your preference for fertilisers reduction"
label variable fertreason "Reason for this fertiliser choice"

********************Lable Values******************
label define ownership 1 "owner" 2 "tenant" 3 "both"
label values ownership ownership
label define gender 1 "Male" 0 "Female"
label values gender gender

```
label define irrsources 1 "canal" 2 "tube-well" 3 "canal & tube-well" 4 "rain" 5 "other"
label values irrsources irrsources
label define irrtypes 1 "flood" 2 "furrow" 3 "drip" 4 "other"
label values irrtypes irrtypes
label define trfertapp 1 "yes" 0 "no"
label values trfertapp trfertapp
label define trpestapp 1 "yes" 0 "no"
label values trpestapp trpestapp
label define pestappadv 1 "extension office" 2 "producer (bottle information)" 3 "pesticides dealer" 4 "other" 5 "pesticides dealer & other" 6 "extension office & pesticides dealer" 7 "extension office & other" 8 "producer (bottle information) & pesticides dealer" 9 "producer (bottle information) & other"
label values pestappadv pestappadv
label define recimpp 1 "exactly" 2 "as a guideline"
label values recimpp recimpp
label define pimpacth  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values pimpacth pimpacth
label define pimpacte  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values pimpacte pimpacte
label define fertappadv 1 "extension office" 2 "producer (bottle information)" 3 "pesticides dealer" 4 "other" 5 "pesticides dealer & other" 6 "extension office & pesticides dealer" 7 "extension office & other" 8 "producer (bottle information) & pesticides dealer" 9 "producer (bottle information) & other"
label values fertappadv fertappadv
label define recimpf 1 "exactly" 2 "as a guideline"
label values recimpf recimpf
label define fimpacth  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values fimpacth fimpacth
label define fimpacte  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values fimpacte fimpacte
label define imppreenv 1 "not important" 2 "somewhat important" 3 "important" 4 "highly important" 5 "do not know"
label values imppreenv imppreenv
label define varieties 1 "20/kg " 2 "40/kg "
label values varieties varieties

*************** tabulations
tab trfertapp // if received any training/advice to apply fertilisers and pesticides
tab pestappadv // advice to apply pesticides
tab fertappadv // advice to apply fertilisers
tab recimpp // implement recomended use of dosage
tab recimpf // implement recomended use of dosage
tab poutbrk // tomato crop outbreak
tab yld33p // decline in yield due to 33% less pesticides
tab size33p // decline in size due to 33% less pesticides
tab yld100p // decline in yield if no pesticide is used
tab size100p // decline in size if no pesticide is used
```

```
tab price33p // tomato price reduction with 33% less pesticides
tab yld33f // decline in yield due to 33% less fertilisers
tab size33f // decline in size due to 33% less fertilisers
tab yld100f // decline in yield if no fertiliser is used
tab size100f // decline in size if no fertiliser is used
tab price33f // tomato price reduction with 33% less fertilisers
tab pimpacth // pesticides impact on health
tab pimpacte // pesticides impact on health
tab fimpacth // fertilisers impact on health
tab fimpacte // fertilisers impact on environment
tab manure // use of manure
tab imppreenv // importance of preserving environment
tab varieties // low and high risk varieties

*************** dummy coding effects
gen owner = (ownership==1) // owner dummy
gen noedu = (edu==0) // no education
gen primedu = (edu !=0 & edu <= 5) //primary education
gen midedu = (edu > 5 & edu < 10) // middle education
gen secabovedu = (edu >= 10) // secondary and above education
gen tomvar = (varieties==2) // low and high risk varieties
gen pesthimp  = (pimpacth==3) | (pimpacth==4) // Pesticides negative impact on health
gen pesteimp  = (pimpacte==3) | (pimpacte==4) // Pesticides negative impact on environment
gen ferthimp  = (fimpacth==3) | (fimpacth==4) // Fertilisers negative impact on health
gen ferteimp  = (fimpacte==3) | (fimpacte==4) // Fertilisers negative impact on environment
gen noyld33p = (yld33p==0) // dummy for no decline in yield with 33% less pestcides
gen nosize33p = (size33p ==0) // dummy for no decline in size with 33% less pestcides
gen noyld100p = (yld100p==0) // dummy for no decline in yield without pestcides
gen nosize100p = (size100p ==0) // dummy for no decline in size without pestcides
gen noyld33f = (yld33f==0) // dummy for no decline in yield with 33% less fertilisers
gen nosize33f = (size33f ==0) // dummy for no decline in size with 33% less fertilisers
gen noyld100f = (yld100f==0) // dummy for no decline in yield without fertilisers
gen nosize100f = (size100f ==0) // dummy for no decline in size without fertilisers
gen pri33p = (price33p > 0) //No reduction in tomato price with 33% less pesticides
gen pri33f = (price33f > 0) //No reduction in tomato price with 33% less fertilisers
```

***************** Regression analysis**

Below is the Stata code used for the estimates reported in Table 4.4 to 4.8 in chapter 4. The regression equations investigate the factors affecting farmer perceptions of the impact of pesticide and fertiliser reduction on tomato crop yield, fruit size and farm gate price.

Stata code for estimates reported in Table 4.4 (Model 1 to 4)

```
******* No decline in yield with 33% less pestcides
probit noyld33p age edu totland owner poutbrk price33p trfertapp onfarmw

 ******* No decline in fruit size with 33% less pestcides
probit nosize33p age edu totland owner poutbrk price33p trfertapp mktdist

******* No decline in yield without pestcide use
probit noyld100p age edu totland owner poutbrk price33p offarminc tomland tomyield
```

******* No decline in fruit size without pestcide use
probit nosize100p age edu onfarmw avprice poutbrk price33p

Stata code for estimates reported in Table 4.5

Table 4.5 presents the average marginal effects of the estimates given in Table 4.4 (Model 1 to 4) using the following Stata command.

margins, dydx(*)

Stata code for estimates reported in Table 4.6 (Model 5 to 8)

******* No decline in yield with 33% less fertilisers
probit noyld33f age edu farminc onfarmw totland pri33f tomland

******* No decline in yield with 33% less fertilisers
probit nosize33f age edu farminc onfarmw totland pri33f

******* No decline in yield without fertiliser use
probit noyld100f age edu poutbrk avprice trfertapp

******* No decline in fruit size without fertiliser use
probit nosize100f age edu poutbrk pri33f tomyield

Stata code for estimates reported in Table 4.7

Table 4.5 presents the average marginal effects of the estimates given in Table 4.6 (Model 5 to 8) using the following Stata command.

margins, dydx(*)

Stata code for estimates reported in Table 4.8

************* Price reductions with 33% pesticide and fertiliser use
probit pri33p edu hhsize farmexp onfarmw tomyield poutbrk

probit pri33f age edu farmexp poutbrk

```
*****************************************************************
//                              DIAGNOSTICS
*****************************************************************
// LINKTEST: This command is used to detect a specification error after the logistic command and
//uses the predicted value (_hat) and predicted value squared (_hatsq) as the predictors to rebuild the model.
//If our model is correctly specified, the prediction squared (hatsq) would have no explanatory power.
//LFIT: This command test the overall goodness of fit of a model.
//FITSTAT: This command computes a variety of measures such as McFadden's R2, McFadden's adjusted R2,
//maximum likelihood R2, AIC, BIC etc.
//linktest
//lfit, group (10) table
//fitstat
//corr
```

```
//vif, uncentered
*outreg2 using results, word append
esttab , se b(%9.3f) scalar(N_clust ll) star(* 0.10 ** 0.05 *** 0.01)
*margins, dydx(*)
*outreg, marginal
*log close
*translate ajaz_consumer.smcl results.txt
*exit
```

G2: Stata routines for consumer data estimates used in Chapter 4

```
 clear all
set more off
*log close
cd "E:\Thesis\Project 1 & 2\Non DCE consumer & farmer\Consumer survey\Stata estimates"
import excel "Remaining consumer survey data", sheet("Sheet1") firstrow
*use consumer.dta, clear
*open log
*log using ajaz_consumer, replace
label variable questionnaire "questionnaire serial no"
label variable age "shoping decision maker age"
label variable gender "shoping decision maker gender, 1=male, 0=female"
label variable edu "shoping decision maker education"
label variable maxedu "household maximum education"
label variable hhsize "household size"
label variable adults "no. of adults in household"
label variable children "no. of children in household"
label variable hhinc "household average monthly income"
label variable tomcon "average consumption of tomato per week (kg)"
label variable awareness "fertilisers and pesticides use awareness in tomato crop"
label variable pestimph "pesticides applied to the vegetables you eat effect on your health"
label variable pestimpe "pesticides applied to the vegetables you eat effect on your environment"
label variable fertimph "fertilisers applied to the vegetables you eat effect on your health"
label variable fertimpe "fertilisers applied to the vegetables you eat effect on your environment"
label variable orgunder "understanding of organic vegetable"
label variable orgimph "impact of organic vegetables consumption on your health"
label variable orgimpe "impact of organic vegetables consumption on environment"
label variable orgcert "certification authority of organic vegetables"
label variable location "location as factor of tomato purchase decision"
label variable fruitsize " fruit size as factor of tomato purchase decision"
label variable color "color as factors of tomato purchase decision"
label variable freshness "freshness as factors of tomato purchase decision"
label variable agrofree "agrochemical free as factors of tomato purchase decision"
label variable co2 "co2 emission as factors of tomato purchase decision"
label variable envpreimp "importance of preserving environment"
label variable healthper "current state of consumer health"
label variable healthcon "consumer health consciousness"
label variable readingrd "you read the ingredients/nutrition facts on food labels"
label variable contnews "read/heard news on food contamination"
label variable excerfreq "how many times a month do you exercise?"
label variable wtp "extra price of tomato you are willing to pay"
```

```
********************Label Values*****************
label define gender 1 "male" 0 "female"
label values gender gender
label define awareness 1 "yes" 0 "no"
label values awareness awareness
label define pestimph  1 "very positively" 2 "positively" 3 "negatively" ///
4"very negatively" 5 "no difference" 6 "donâ€™t know"
label values pestimph pestimph
label define pestimpe  1 "very positively" 2 "positively" 3 "negatively" ///
4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values pestimpe pestimpe
label define fertimph  1 "very positively" 2 "positively" 3 "negatively" ///
4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values fertimph fertimph
label define fertimpe  1 "very positively" 2 "positively" 3 "negatively" ///
4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values fertimpe fertimpe
label define orgunder 1 "yes" 0 "no"
label values orgunder orgunder
label define orgimph  1 "very positively" 2 "positively" 3 "negatively" ///
4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values orgimph orgimph
label define orgimpe  1 "very positively" 2 "positively" 3 "negatively" ///
4 "very negatively" 5 "no difference" 6 "donâ€™t know"
label values orgimpe orgimpe
label define orgcert  1 "government" 2 "private company" 3 "international organization"
label values orgcert orgcert
label define envpreimp  1 "not important" 2 "somewhat important" 3 "important" ///
4 "highly important" 5 "do not know"
label values envpreimp  envpreimp
label define healthper  1 "bad" 2 "poor" 3 "alright" 4 "good" 5 "very good"
label values healthper healthper
label define healthcon 1 "yes" 2 "no" 3 "somewhat health conscious"
label values healthcon healthcon
label define readingrd  1 "quiet often" 2 "rarely" 3 "never"
label values readingrd readingrd

*generate LocDummy = Location <4
*generate SizDummy = Size <4
*generate ColDummy = Color <4
*generate FreshDummy = Freshness <4
*generate AgroDummy = Agrofree <4
*generate CO2Dummy = CO2 <4
*generate CertiDummy = OrgCert >1
*generate HConcDummy = HealthConc == 2
gen goodhealth = (healthper > 2)
gen hconci = ( healthcon ==1) | ( healthcon ==3)
gen ringrednts = ( readingrd ==1) | ( readingrd ==2)
gen secedu = ( edu<= 12) // secondary education
gen colledu = (edu > 12 & edu < 15) // college education
```

```
gen uniedu = (edu >= 15) // university education
gen genedu = gender*edu
```

**********************Regression analysis******************

Below is the Stata code used for the estimates reported in Table 4.10 and 4.11 in chapter 4. The regression equations investigate the factors affecting consumer awareness of fertiliser and pesticide use in tomato crop and their understanding of organic vegetable.

Stata code for estimates reported in Table 4.10

```
********** Awareness of fertilisers and pesticides use in tomato crop
probit awareness age gender edu tomcon orgunder goodhealth ringrednts
margins, dydx(*)
```

Stata code for estimates reported in Table 4.11

```
********* Understanding of organic vegetables
probit orgunder age gender edu awareness ringrednts contnews wtp children
margins, dydx(*)

************diagnostics***************
*vce, corr
*vif, uncentered
*outreg2 using results, word append
*margins, dydx(*)
*outreg, marginal
esttab, se b(%9.3f) scalar(N_clust ll) star(* 0.10 ** 0.05 *** 0.01)
*log close
*translate ajaz_consumer.smcl results.txt
*exit
```

G3: Stata routines used for DCE analysis of farmer data in Chapter 5

```
clear all
set more off
cd "J:\PhD Research\Thesis\Project 1 & 2\Farmer survey\Second round"
cd "E:\PhD research\Thesis\Project 1 & 2\DCE farmers\New estimates"
use farmer.dta, clear
* open log
*log using ajaz_farmer, replace
***************Variable Labels*******************
label variable consid "Questionnaire serial no"
label variable csetid "Choice set progressive no"
label variable cset "Choice situations in experimental design from 1-60"
label variable alt "Options in each choice situation/Choice card i.e. Alt1=1, Alt2=2, No change=3"
label variable y "Response/Chosen option 1=chosen, 0=otherwise"
label variable Irrig "Irrigation attribute 0= furrow, 1= drip"
label variable Fert "Fertiliser attribute 0=unrestricted, 0=unrestricted, 1=33% less, 2=50% less)"
label variable Pest "Pesticides attribute 0=unrestricted, 1=25% less, 2=33% less"
label variable Price "Price premium/extra price per kg attribute"
label variable Ownership "Ownership status 1=owner, 2=tanent, 3=both (Ownership+lease)"
```

label variable Gender "Farm decision maker gender"
label variable Age "Farm decision maker age"
label variable Edu "Farm decision maker education"
label variable MaxEdu "Household maximum education"
label variable HHsize "Total household size"
label variable FarmExp "Farm decision maker farming experience"
label variable MktDist "Distance to nearest market"
label variable FarmInc "Household on-farm average net seasonal income"
label variable OffarmInc "Household off-farm monthly income"
label variable TotalInc "Household total income"
label variable OnfarmW "Household members working on-farm"
label variable OffarmW "Household members working off-farm"
label variable TotLand "Total cultivable land (acres)"
label variable GrainLand "Cultivable land for grains (acres)"
label variable VegLand "Cultivable land for vegetables (acres)"
label variable TomLand "Cultivable land for other tomato (acres)"
label variable OtherLand "Cultivable land for other crops (acres)"
label variable TomYield "Tomato yield/per crop cycle (mounds)"
label variable AvPrice "Average farm gate price of tomato/mound"
label variable MinPrice "Minimum farm gate price of tomato/mound"
label variable MaxPrice "Maximum farm gate price of tomato/mound"
label variable IrrSources "Tomato irrigation sources"
label variable IrrTypes "Irrigation types"
label variable TrFertApp "Training/advice for fertiliser application"
label variable TrPestApp "Training/advice for pesticides application"
label variable PestAppAdv "Whose advise do you follow when applying pesticide(s)"
label variable RecImpP "How do you implement the recommendation"
label variable Pest1 "Per acre use of pesticide 1 (potterton c) ml"
label variable Water1 "Water (ltrs) to dilute pesticide 1"
label variable Pest2 "Per acre use of pesticide 2 (kava karan) ml"
label variable Water2 "Water (ltrs) to dilute pesticide 2"
label variable Pest3 "Per acre use of pesticide 3 (grow up)(gm)"
label variable Water3 "Water (ltrs) to dilute pesticide 3"
label variable Pest4 "Per acre use of pesticide 4 (timer) gm"
label variable Water4 "Water (ltrs) to dilute pesticide 4"
label variable Pest5 "Per acre use of pesticide 5 (lambda) ml"
label variable Water5 "Water (ltrs) to dilute pesticide 5"
label variable Pest6 "Per acre use of pesticide 6 (escore) gm"
label variable Water6 "Water (ltrs) to dilute pesticide 6"
label variable POutbrk "No. of times you experienced a major tomato crop pest or weed outbreak in last 5 years"
label variable Yld33P "Approximate decline in yield/acre (%) if all pesticides are reduced by 33%"
label variable Size33P "Approximate decline in average size (%) if all pesticides are reduced by 33%"
label variable Yld100P "Approximate decline in yield/acre (%) if no pesticides are applied"
label variable Size100P "Approximate decline in average size (%) if no pesticides are applied"
label variable Price33P "Price reduction (Rs/mound) if pesticides use is reduced by 33%"
label variable PImpactH "Pesticides applied to tomatoes affect on health"
label variable PImpactE "Pesticides applied to tomatoes affect on environment"
label variable Urea "Per acre use (kg) of urea for tomato crop"
label variable DAP "Per acre use (kg) of DAP for tomato crop"
label variable Nitroph "Per acre use (kg) of nitrophosphate for tomato crop"

label variable Potash "Per acre use (kg) of potash for tomato crop"
label variable AmunNit "Per acre use (kg) of ammunium nitrate for tomato crop"
label variable Manure "Total manure you use in tomato crop (tons)"
label variable FertAppAdv "Whose advise do you follow when applying fertiliser(s)"
label variable RecImpF "How do you implement the recommendation"
label variable Yld33F "Approximate decline in tomato yield/acre (%) if all fertilisers are reduced by 33%"
label variable Size33F "Approximate decline in tomato average size (%) if all fertilisers are reduced by 33%"
label variable Yld100F "Approximate decline in tomato yield/acre (%) if no fertilisers are applied"
label variable Size100F "Approximate decline in average tomato size (%) if no fertilisers are applied"
label variable Price33F "Tomato price reduction (Rs/mound) if fertilisers use is reduced by 33%"
label variable FImpactH "Fertilisers applied to tomatoes affect on health"
label variable FImpactE "Fertilisers applied to tomatoes affect on environment"
label variable ImpPreEnv "Importance of preserving the environment"
label variable Varieties "Choice of tomato varieties"
label variable IrriPref "What is your preference for irrigation"
label variable IrriReason "Reason for this irrigation choice"
label variable PestPref "What is your preference for pesticide reduction"
label variable PestReason "Reason for this pesticides choice"
label variable FertPref "What is your preference for fertilisers reduction"
label variable FertReason "Reason for this fertiliser choice"

*********************Lable Values******************
*label define Ownership 1 "owner" 2 "tenant" 3 "both"
*label values Ownership Ownership
*label define Gender 1 "Male" 0 "Female"
*label values Gender Gender
*label define IrrSources 1 "canal" 2 "tube-well" 3 "canal & tube-well" 4 "rain" 5 "other"
*label values IrrSources IrrSources
*label define IrrTypes 1 "flood" 2 "furrow" 3 "drip" 4 "other"
*label values IrrTypes IrrTypes
*label define TrFertApp 1 "yes" 0 "no"
*label values TrFertApp TrFertApp
*label define TrPestApp 1 "yes" 0 "no"
*label values TrPestApp TrPestApp
*label define PestAppAdv 1 "extension office" 2 "producer (bottle information)" 3 "pesticides dealer" 4 "other" 5 "pesticides dealer & other" 6 "extension office & pesticides dealer" 7 "extension office & other" 8 "producer (bottle information) & pesticides dealer" 9 "producer (bottle information) & other"
*label values PestAppAdv PestAppAdv
*label define RecImpP 1 "exactly" 2 "as a guideline"
*label values RecImpP RecImpP
*label define PImpactH 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values PImpactH PImpactH
*label define PImpactE 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values PImpactE PImpactE
*label define FertAppAdv 1 "extension office" 2 "producer (bottle information)" 3 "pesticides dealer" 4 "other" 5 "pesticides dealer & other" 6 "extension office & pesticides dealer" 7 "extension office & other" 8 "producer (bottle information) & pesticides dealer" 9 "producer (bottle information) & other"

```
*label values FertAppAdv FertAppAdv
*label define RecImpF 1 "exactly" 2 "as a guideline"
*label values RecImpF RecImpF
*label define FImpactH  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values FImpactH FImpactH
*label define FImpactE  1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values FImpactE FImpactE
*label define ImpPreEnv 1 "not important" 2 "somewhat important" 3 "important" 4 "highly important" 5 "do not know"
*label values ImpPreEnv ImpPreEnv
*label define Varieties 1 "20/kg " 2 "40/kg "
*label values Varieties Varieties

*************** dummy coding effects
*gen ir1 = (Irrig==1)
*gen fe1 = (Fert==1)
*gen fe2 = (Fert==2)
*gen pe1 = (Pest==1)
*gen pe2 = (Pest==2)
*gen sq = (alt==3)
*gen pri = Price
*gen const = 1
*gen npr=-pri

*******Define attribute strings
global rhsx "sq ir1 fe1 fe2 pe1 pe2 pri"
global rhsw "sq ir1 fe1 fe2 pe1 pe2"
****************Interactions
***********income interaction
gen sqinc = sq*TotalInc
gen ir1inc = ir1*TotalInc
gen fe1inc = fe1*TotalInc
gen fe2inc = fe2*TotalInc
gen pe1inc = pe1*TotalInc
gen pe2inc = pe2*TotalInc
gen priinc = pri*TotalInc

***********education interaction
gen sqedu = sq*Edu
gen ir1edu = ir1*Edu
gen fe1edu = fe1*Edu
gen fe2edu = fe2*Edu
gen pe1edu = pe1*Edu
gen pe2edu = pe2*Edu
gen priedu = pri*Edu

***********age interaction
gen sqage = sq*Age
gen ir1age = ir1*Age
```

```
gen fe1age = fe1*Age
gen fe2age = fe2*Age
gen pe1age = pe1*Age
gen pe2age = pe2*Age
gen priage = pri*Age

***********pri interaction
gen sqpri = sq*pri
gen ir1pri = ir1*pri
gen fe1pri = fe1*pri
gen fe2pri = fe2*pri
gen pe1pri = pe1*pri
gen pe2pri = pe2*pri

***********hhsize interaction
gen sqhhsize = sq*HHsize
gen ir1hhsize = ir1*HHsize
gen fe1hhsize = fe1*HHsize
gen fe2hhsize = fe2*HHsize
gen pe1hhsize = pe1*HHsize
gen pe2hhsize = pe2*HHsize
gen prihhsize = pri*HHsize

***********farming experience interaction
gen sqfarmexp = sq*FarmExp
gen ir1farmexp = ir1*FarmExp
gen fe1farmexp = fe1*FarmExp
gen fe2farmexp = fe2*FarmExp
gen pe1farmexp = pe1*FarmExp
gen pe2farmexp = pe2*FarmExp
gen prifarmexp = pri*FarmExp

***********farming experience interaction
gen sqfgpri = sq*AvPrice
gen ir1fgpri = ir1*AvPrice
gen fe1fgpri = fe1*AvPrice
gen fe2fgpri = fe2*AvPrice
gen pe1fgpri = pe1*AvPrice
gen pe2fgpri = pe2*AvPrice
gen prifgpri = pri*AvPrice

***********Summary statistics
sum Irrig Fert Pest Price Age Edu MaxEdu HHsize FarmExp MktDist FarmInc OffarmInc ///
TotalInc OnfarmW OffarmW TotLand TomLand AvPrice IrrSources IrrTypes

***************Graphs***************
hist FarmInc
hist MaxEdu
hist Edu

*********************Mixed logit model in preference space************
```

A mixed logit model is estimated in preference-space for farmer survey data and results are reported in Table 5.3 and 5.4 in chapter 5. Table 5.3 reports the results of the base model and Table 5.4 presents the model with attribute interactions. WTA estimates are reported in Table 5.5. Below is the Stata code used to estimate a mixed logit model in preference space.

Stata code for base model reported in Table 5.3

************Mixed logit- all normally distributed coefficients except fixed price**

```
mixlogit y pri, rand($rhsw) group(csetid) id(consid) nrep(1000) difficult iterate(200)
*outreg2 using results, word append
```

Stata code for model with attribute interactions reported in Table 5.4

*************Mixed logit- all normally distributed coefficients except price and interaction terms***

```
mixlogit y pri pe1edu pe2edu, rand($rhsw) group(csetid) id(consid) nrep(1000) ///
difficult iterate(200)
```

Stata code for farmer WTA distribution reported in Table 5.5

```
nlcom (-_b[ir1]) /_b[pri]
nlcom (-_b[fe1]) /_b[pri]
nlcom (-_b[fe2]) /_b[pri]
nlcom (-_b[pe1]) /_b[pri]
nlcom (-_b[pe2]) /_b[pri]
nlcom (_b[pe1]+_b[pe1edu]*6.613) /(-_b[pri])
nlcom (_b[pe2]+_b[pe2edu]*6.613) /(-_b[pri])
```

Stata code for percentiles of farmer WTA distribution reported in Table 5.6

First, individual level estimates were produced using the Stata command 'mixlbeta' which allowed to derive individual level WTAs, and then Stata command 'centile' was used to generate the farmer WTA percentiles.

Stata code for individual level estimates

```
mixlbeta $rhsx, saving(individualestimates)
```

Stata code for WTA percentiles

```
centile (wtair1 wtafe1 wtafe2 wtape1 wtape2), centile (10 20 25 50 75 80 90)
```

*************************Mixed logit model in Price-space ***************

A mixed logit model in Price-space is also estimated for farmer survey data and results are reported in Table 5.8 in chapter 5. Correlation between coefficients in Price-space model is presented in Table 5.9. Below is the Stata code used to estimate a mixed logit model in Price-space and produce correlation matrix.

Stata code for mixed logit model in Price-space reported in Table 5.7

**********Mixed logit in Price-space with random coefficients (non zero st. dev., but 0 corr.)***

```
matrix start =  st,-4.2,J(1,7,2)
mixlogitwtp y, group(csetid) price(pri) id(consid) nrep(500) difficult rand($rhsw) iterate(200) trace
from(start, copy)
```

G4: Stata routines used for DCE analysis of consumer data in Chapter 6

```
clear all
set more off
* set the path to your own directory where .dta file is
cd "J:\PhD Research\Thesis\Project 1 & 2\Consumer survey\Second round"
use consumer.dta, clear
* open log
*log using ajaz_consumer, replace
* import excel "Consumer survey data.xlsx", sheet("Labeled data") firstrow
***************Variable Labels*******************
label variable consid "Questionnaire serial no"
label variable csetid "Choice set progressive no"
label variable cset "Choice situations in experimental design from 1-60"
label variable alt "Options in each choice situation/Choice card i.e. Alt1=1, Alt2=2, No change=3"
label variable y "Preferred Alternative option 1=chosen, 0=otherwise"
label variable Irrig "Irrigation attribute 0=flood, 1=furrow, 2= drip"
label variable Fert "Fertiliser attribute 0=unrestricted, 1=unrestricted, 2=33% less, 3=50% less)"
label variable Pest "Pesticides attribute 0=unrestricted, 1=25% less, 2=33% less"
label variable Insp "Inspection attribute 0= no inspection, 1=twice, 2= 4 times"
label variable Price "Price premium/extra price per kg attribute"
label variable Prob "Probability (%) of choosing the selected choice out of 20"
label variable Age "Shoping decision maker age"
label variable Gender "Shoping decision maker gender, 1=male, 0=female"
label variable Edu "Shoping decision maker education"
label variable MaxEdu "Household maximum education"
label variable HHSize "Total household size"
label variable Adults "No. of adults in household"
label variable Kids "No. of kids in household"
label variable HHInc "Household average monthly income"
label variable TomCon "Average consumption of tomato per week (kg)"
label variable Awareness "Fertilisers and pesticides use awareness in tomato crop"
label variable PImpactH "Pesticides applied to the vegetables you eat effect on your health"
label variable PImpactE "Pesticides applied to the vegetables you eat effect on your environment"
label variable FImpactH "Fertilisers applied to the vegetables you eat effect on your health"
label variable FImpactE "Fertilisers applied to the vegetables you eat effect on your environment"
label variable OrgDef "Definition of organic vegetable"
label variable OrgImpactH "Impact of organic vegetables consumption on your health"
label variable OrgImpactE "Impact of organic vegetables consumption on environment"
label variable OrgCert "Certification authority of organic vegetables"
label variable Location "Location as factors of tomato purchase decision"
label variable Size "Size as factors of tomato purchase decision"
label variable Color "Color as factors of tomato purchase decision"
label variable Freshness "Freshness as factors of tomato purchase decision"
label variable Agrofree "Agrochemical free as factors of tomato purchase decision"
label variable CO2 "CO2 emission as factors of tomato purchase decision"
label variable ImpPreEnv "Importance of preserving environment"
label variable CurHealth "Current state of consumer health"
label variable HealthConc "Consumer health consciousness"
label variable ReadIngrd "You read the ingredients/nutrition facts on food labels"
label variable ContNews "Read/heard news on food contamination"
label variable ExcerFreq "How many times a month do you exercise?"
```

label variable WTP "Extra price of tomato you are WTP"

********************Label Values******************
*label define Gender 1 "Male" 0 "Female"
*label values Gender Gender
*label define Awareness 1 "yes" 0 "no"
*label values Awareness Awareness
*label define PImpactH 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values PImpactH PImpactH
*label define PImpactE 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values PImpactE PImpactE
*label define FImpactH 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values FImpactH FImpactH
*label define FImpactE 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values FImpactE FImpactE
*label define OrgDef 1 "yes" 0 "no"
*label values OrgDef OrgDef
*label define OrgImpactH 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values OrgImpactH OrgImpactH
*label define OrgImpactE 1 "very positively" 2 "positively" 3 "negatively" 4 "very negatively" 5 "no difference" 6 "donâ€™t know"
*label values OrgImpactE OrgImpactE
*label define OrgCert 1 "government" 2 "private company" 3 "international organization"
*label values OrgCert OrgCert
*label define ImpPreEnv 1 "not important" 2 "somewhat important" 3 "important" 4 "highly important" 5 "do not know"
*label values ImpPreEnv ImpPreEnv
*label define CurHealth 1 "bad" 2 "poor" 3 "alright" 4 "good" 5 "very good"
*label values CurHealth CurHealth
*label define HealthConc 1 "yes" 2 "no" 3 "somewhat health conscious"
*label values HealthConc HealthConc
*label define ReadIngrd 1 "quiet often" 2 "rarely" 3 "never"
*label values ReadIngrd ReadIngrd

**************** dummy coding effects**
*gen ir1 = (Irrig==1)
*gen ir2 = (Irrig==2)
*gen in1 = (Insp==1)
*gen in2 = (Insp==2)
*gen fe1 = (Fert==1)
*gen fe2 = (Fert==2)
*gen pe1 = (Pest==1)
*gen pe2 = (Pest==2)
*gen sq = (alt==3)
*gen pri = Price
*gen const = 1

```
*gen npr=-pri

drop if (consid == 211)
drop if (consid == 178)
drop if (consid == 179)

*******Define attribute strings
global rhsx "sq ir1 ir2 fe1 fe2 pe1 pe2 in1 in2 pri"
global rhsw "sq ir1 ir2 fe1 fe2 pe1 pe2 in1 in2"

****************Interactions with sq, pri, age, education and income
***********income interaction
gen sqinc = sq*HHInc
gen ir1inc = ir1*HHInc
gen ir2inc = ir2*HHInc
gen fe1inc = fe1*HHInc
gen fe2inc = fe2*HHInc
gen pe1inc = pe1*HHInc
gen pe2inc = pe2*HHInc
gen in1inc = in1*HHInc
gen in2inc = in2*HHInc
gen priinc = pri*HHInc
***********gender interaction
gen sqgender = sq*Gender
gen ir1gender = ir1*Gender
gen ir2gender = ir2*Gender
gen fe1gender = fe1*Gender
gen fe2gender = fe2*Gender
gen pe1gender = pe1*Gender
gen pe2gender = pe2*Gender
gen in1gender = in1*Gender
gen in2gender = in2*Gender
gen prigender = pri*Gender
***********education interaction
gen sqedu = sq*Edu
gen ir1edu = ir1*Edu
gen ir2edu = ir2*Edu
gen fe1edu = fe1*Edu
gen fe2edu = fe2*Edu
gen pe1edu = pe1*Edu
gen pe2edu = pe2*Edu
gen in1edu = in1*Edu
gen in2edu = in2*Edu
gen priedu = pri*Edu
***********age interaction
gen sqage = sq*Age
gen ir1age = ir1*Age
gen ir2age = ir2*Age
gen fe1age = fe1*Age
gen fe2age = fe2*Age
gen pe1age = pe1*Age
```

```
gen pe2age = pe2*Age
gen in1age = in1*Age
gen in2age = in2*Age
gen priage = pri*Age
***********pri interaction
gen sqpri = sq*pri
gen ir1pri = ir1*pri
gen ir2pri = ir2*pri
gen fe1pri = fe1*pri
gen fe2pri = fe2*pri
gen pe1pri = pe1*pri
gen pe2pri = pe2*pri
gen in1pri = in1*pri
gen in2pri = in2*pri
***********hhsize interaction
gen sqhhsize = sq*HHSize
gen ir1hhsize = ir1*HHSize
gen ir2hhsize = ir2*HHSize
gen fe1hhsize = fe1*HHSize
gen fe2hhsize = fe2*HHSize
gen pe1hhsize = pe1*HHSize
gen pe2hhsize = pe2*HHSize
gen in1hhsize = in1*HHSize
gen in2hhsize = in2*HHSize
gen prihhsize = pri*HHSize
***********awareness interaction
gen sqaware = sq*Awareness
gen ir1aware = ir1*Awareness
gen ir2aware = ir2*Awareness
gen fe1aware = fe1*Awareness
gen fe2aware = fe2*Awareness
gen pe1aware = pe1*Awareness
gen pe2aware = pe2*Awareness
gen in1aware = in1*Awareness
gen in2aware = in2*Awareness
gen priaware = pri*Awareness
***********hhsize interaction
gen sqkids = sq*Kids
gen ir1kids = ir1*Kids
gen ir2kids = ir2*Kids
gen fe1kids = fe1*Kids
gen fe2kids = fe2*Kids
gen pe1kids = pe1*Kids
gen pe2kids = pe2*Kids
gen in1kids = in1*Kids
gen in2kids = in2*Kids
gen prikids = pri*Kids
**************Graphs**************
hist Edu
hist MaxEdu
hist HHInc
```

***********************Mixed logit model in preference space************

A mixed logit model is estimated in preference-space for consumer survey data and results are reported in Table 6.3 and 6.4 in chapter 6. Table 6.3 reports the results of the base model and Table 6.4 presents the model with attribute interactions. WTA estimates are reported in Table 6.5. Below is the Stata code used to estimate a mixed logit model in preference space.

Stata code for base model reported in Table 6.3

***********Mixed logit- all normally distributed coefficients except fixed price***

```
mixlogit y pri, rand($rhsw) group(csetid) id(consid) nrep(1000) difficult iterate(200)
*outreg2 using results, word append
```

Stata code for model with attribute interactions reported in Table 6.4

*********Mixed logit- all normally distributed coefficients except price and interaction terms***

```
mixlogit y fe2kids in2kids ir1gender pri, rand($rhsw) group(csetid) id(consid) nrep(1000) difficult iterate(200)
```

Stata code to derive the WTP from preference-space models reported in Table 6.5

```
nlcom (-_b[ir1]) /_b[pri]
nlcom (-_b[ir2]) /_b[pri]
nlcom (-_b[fe1]) /_b[pri]
nlcom (-_b[fe2]) /_b[pri]
nlcom (-_b[pe1]) /_b[pri]
nlcom (-_b[pe2]) /_b[pri]
nlcom (-_b[in1]) /_b[pri]
nlcom (-_b[in2]) /_b[pri]
nlcom (_b[ir1]+_b[ir1gender]*0.313) /(-_b[pri])
nlcom (_b[fe2]+_b[fe2kids]*1.556) /(-_b[pri])
nlcom (_b[in2]+_b[ in2kids ]*1.556) /(-_b[pri])
```

Stata code for percentiles of consumer WTP distribution presented in Table 6.6

First, individual level estimates were produced using the Stata command 'mixlbeta' which allowed to derive individual level WTPs, and then Stata command 'centile' was used to generate the consumer WTP percentiles.

Stata code for individual level estimates

```
mixlbeta $rhsx, saving(individualestimates)
```

Stata code for WTP percentiles

```
centile (wtpir1 wtpir2 wtpfe1 wtpfe2 wtppe1 wtppe2 wtpin1 wtpin2), centile(10 20 25 50 75 80 90)
```

***********************Mixed logit model in Price-space ************

A mixed logit model in Price-space is also estimated for consumer survey data and results are reported in Table 6.7 in chapter 6. Below is the Stata code used to estimate a mixed logit model in Price-space.

Stata code for mixed logit model in Price-space reported in Table 6.7

********Mixed logit in Price-space with random coefficients (non zero st. dev., but 0 corr.)***

```
matrix start = -16.70, 3.30, 7.44, 5.229, 7.74, 1.78, 3.18, 8.84, 10.88862, ///
-2.654,7.59, .4081, -2.5, -1.859, 10.15, 4.26, 11.43, 18.68, 17.119, .648
```

```
mixlogitwtp y, group(csetid) price(npr) id(consid) nrep(1000) difficult ///
rand($rhsw) iterate(200) trace from(start, copy)
```