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Impact of Land Tenure Arrangements, Bt Cotton Adoption and Market Participation on Welfare of Farm Households in Rural Pakistan

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Summary

Genetically modified cotton was first time introduced during 1996 in USA and Australia. Since then, many cotton producing countries have commercialized the production of Bt cotton. Pakistan is the fourth largest cotton producing country in the world after China, USA and India. Cotton and cotton products contribute about 3.2 % to GDP and 60-65% to foreign exchange earnings of the country. Cotton production supports millions of farm families in Pakistan. Recently Bt cotton varieties are grown by farmers in Pakistan and adoption rate is quite high as more than 75% area is under Bt cotton varieties. The present study is the first Bt cotton adoption and impact evaluation study in Pakistan. Moreover, important focus is on the influence of land rights on the farmers' decision to invest in land improvement measures and efficiency level. Due to highly skewed land distribution pattern in Pakistan, one third of the farmers are tenant farmers. Tenant farmers have few land rights and very less resources. Therefore, in the present study land rights' influence on farmers' decision to invest in land improvement measures and efficiency levels is estimated. Literature on farmers' market participation is mostly missing in the past, particularly in Pakistan, and only few studies have analyzed farmers' market participation. Farmers' market participation is affected by household resources and credit constraints. Three important aspects of cotton production and marketing are focused in this dissertation i.e. adoption and impact of Bt cotton, land rights' influence on farmers' decision to invest in land improvement measures and efficiency level, and cotton farmers, access to markets. These three important aspects has been mostly ignored in the past.

For the study, cross sectional data set of 325 cotton farmers has been collected in 2007 from seven highest cotton producing districts in the Punjab province of Pakistan. These seven districts together produce nearly 50% cotton of Pakistan. The study estimates the adoption and impact of Bt cotton on household welfare by employing the propensity score matching approach. Propensity score matching is non-parametric method. Hence, no functional form assumptions are needed. Propensity score creates the condition of a randomized experiment by constructing the control group. Land rights' influence on farmers' decision to invest in land improvement measures is estimated by employing the multivariate Tobit model, while cotton producers' technical, allocative and economic efficiencies are estimated by employing translog profit and cost frontier models. The propensity score matching approach is employed to examine the direct effects of investment in the productivity enhancing measures on farm

productivity and efficiency. For the cotton marketing analysis, a number of different models are employed, to investigate the farmers' market participation and its impact on net returns. Probit model is employed for farmers' market participation and results have been instrumented for credit (advance money) taken from local trader (commission agent). The Tobit and censored least absolute deviation (CLAD) models were employed for distance travelled to sell cotton, while Heckman selection estimator was employed for quantity of cotton sold in the market. The propensity score matching estimator was employed for estimating cotton net returns.

The results regarding adoption and impact of genetically modified cotton indicates that Bt cotton adoption has positive and significant impact on cotton yields and household income while negative and significant impact on pesticide demand and poverty status of the household. In detail, the results indicate that adopters of Bt cotton technology are getting 50-60 kg per acre higher yields, while the average household incomes are higher by rupees 16500-17000. The demand for pesticide is lower among adopter households in the range of 0.62-0.68 litres per acre. The probability of adopters being poor is found to be lower by about 13.5-14.3%, relative to non-adopters. The farming categories (small, medium and large) results indicate that new technology has a beneficial impact among small, medium as well as large scale farming households. Particularly Bt cotton can help to reduce poverty among small scale farmers. The finding are very much in line with the previous studies on Bt cotton adoption and impact evaluation in different countries like China, India and Argentina.

The results of land rights influence on farmers' decision to invest in land improvement measures and efficiency level indicate that farmers with secure land rights invest more in land improvement measures i.e. farm yard manure, mineral fertilizer and leguminous crops. The estimates reveal that owner-cultivated lands exhibit the highest levels of technical, allocative and economic efficiency. Specifically, the allocative efficiency for owner-cultivated, fixed-renters and sharecroppers are 92, 85 and 82%, while the corresponding figures for technical efficiency are 86, 80 and 77%, respectively. Similarly, the economic efficiency of owner-cultivated, fixed renters and sharecroppers are 78, 68 and 62%, respectively. The results indicates that owners are technically, allocativelly and economically more efficient as compared to sharecropper and fixed renters. The fixed renters are technically, allocativelly and economically more efficient as compared to sharecroppers.

The results of farmers' market participation indicate that farmers' market participation is influenced by the farmers' resources and households' wealth. Compared to resource poor farmers, large farmers have easier access to markets. Wealthier households can travel longer distances for cotton selling and are also in a position to sell larger volumes of cotton in the market. The net returns are positive and significant for the farmers selling at market compared to the farmers selling at farm gate.

The present study provides important policy implications, since the adoption of the Bt cotton technology has a significantly positive impact on cotton yields, household income and poverty reduction, and a negative impact on the use of pesticides. Especially, targeting the small-scale farmers with new agricultural technology can help improving their farm productivity, household income and reduce poverty among these households. Policies in this direction include increasing cotton farmers' access to information to reduce uncertainty about new technologies and formal credit for them to overcome liquidity constraints. Additionally, improving their human capital in the form of education and providing them with better infrastructure, as well as advanced extension services, can help in adoption of Bt cotton technology. Since owners are technically, allocativelly and economically more efficient as compared to tenants, hence tenants should be provided land rights through land reforms. This will encourage the small-scale farmers to invest in land improvement measures and hence higher levels of technical, allocative and economic efficiency can be achieved, which will be helpful in increasing the cotton productivity at national level. Cotton marketing results indicate that currently the wealthy households have easy access to markets. Farmers with market participation are getting higher net returns compared to farmers selling at the farm gate. Small-scale farmers can be linked to markets by investing in human capital, improving the village infrastructure and making the formal credit programme easy for small-scale farmers.

Zusammenfassung

Im Jahr 1996 wurde in den USA und Australien zum ersten Mal gentechnisch veränderte Baumwolle eingesetzt. Seitdem haben viele Baumwolle produzierende Länder die Produktion von Bt-Baumwolle kommerzialisiert. Pakistan ist nach China, den USA und Indien der viertgrößte Baumwollproduzent der Welt und Baumwolle und Baumwollprodukte machen 3,2% des BIP und 60% bis 65% der Deviseneinnahmen des Landes aus. Die Baumwollproduktion unterstützt Millionen Familienbetriebe. Neuerdings werden verschiedene Bt-Baumwollsorten von Landwirten in Pakistan angebaut und die Einführungsrate ist sehr hoch, wobei mittlerweile mehr als 75% des Landes mit verschiedenen Bt-Baumwollsorten bewirtschaftet werden. Die vorliegende Studie ist die erste Studie, die sich mit der Annahme der Bt-Baumwolle und der Auswirkungsbewertung in Pakistan befasst. Darüber hinaus liegt der Schwerpunkt auch auf dem Einfluss von Bodenrechten auf die Entscheidung der Landwirte, in Bodenverbesserungsmaßnahmen und den Wirkungsgrad zu investieren. Aufgrund der stark verzerrten Bodenverteilungsstruktur in Pakistan sind ein Drittel der Landwirte Pächter. Pächter haben nur wenige Bodenrechte und sehr wenige Ressourcen. Aus diesem Grund wird der Einfluss der Bodenrechte auf die Entscheidung der Landwirte, in Bodenverbesserungsmaßnahmen und den Wirkungsgrad zu investieren, in dieser Studie untersucht.

Es gibt bisher kaum Literatur bezüglich der Marktteilnahme der Landwirte in Pakistan und insgesamt haben nur wenige Studien die Marktteilnahme der Landwirte untersucht. Die Marktteilnahme der Landwirte wird durch die Haushaltsressourcen und Krediteinschränkungen beeinflusst. Drei wichtige Aspekte der Baumwollproduktion werden beleuchtet, nämlich die Annahme der Bt-Baumwolle und deren Auswirkungen, der Einfluss der Bodenrechte auf die Entscheidung der Landwirte, in Bodenverbesserungsmaßnahmen und den Wirkungsgrad zu investieren, und der Zugang zu Märkten für die Baumwollproduzenten. Diese drei Aspekte wurden in der Vergangenheit kaum berücksichtigt.

Für diese Studie wurde im Jahr 2007 in den 7 produktionsstärksten Bezirken der pakistanischen Provinz Punjab ein Querschnittsdatensatz mit 325 Baumwollproduzenten erhoben. Diese 7 Bezirke zusammen genommen produzieren knapp 50% der gesamten Baumwolle in Pakistan. Mit Hilfe der *Propensity Score Matching*-Methode werden in dieser Studie die Annahme der Bt-Baumwollproduktion und die Auswirkungen der Produktion auf die Wohlfahrt der Haushalte untersucht. *Propensity Score Matching* ist eine nichtparametrische Methode und benötigt daher

keine Annahme zur funktionalen Form. Das Verfahren schafft die Bedingungen eines randomisierten Experiments, indem eine Kontrollgruppe gebildet wird. Der Einfluss der Bodenrechte auf die Investitionsentscheidung der Landwirte wird mit Hilfe eines multivariaten *Tobit*-Modells geschätzt, während die technischen, allokativen und wirtschaftlichen Leistungen der Baumwollproduzenten mittels Translog-Gewinn- und Kostengrenzmodellen untersucht werden. Das *Propensity Score Matching*-Verfahren wird verwendet, um die direkten Auswirkungen der Investitionen in Produktivitätssteigerungsmaßnahmen auf die landwirtschaftliche Produktivität und Leistung zu beleuchten. Zum Zwecke der Analyse des Baumwollmarketing finden verschiedene Modelle Anwendung, um die Marktteilnahme der Landwirte und deren Einfluss auf den Nettoertrag zu untersuchen. Für die Marktteilnahme der Landwirte wird ein *Probit*-Modell angewandt und die Ergebnisse werden als Kredit (Vorschuss) vom Händler (Kommissionär) instrumentiert. Die *Tobit*- und *CLAD*-Modelle werden für die zurückgelegte Entfernung zum Baumwollverkauf angewandt, während der *Heckman*-Selektionsschätzer für die auf dem Markt verkaufte Menge an Baumwolle verwendet wird. Die *Propensity Score Matching*-Methode wird für die Analyse der Nettoerträge der Baumwolle herangezogen.

Die Ergebnisse bezüglich Annahme und Auswirkung der gentechnisch veränderten Baumwolle deuten darauf hin, dass Bt-Baumwolle signifikant positive Auswirkungen auf die Baumwollerträge und das Haushaltseinkommen hat und dazu signifikant negative Auswirkungen auf den Pestizidverbrauch und die Armutssituation des Haushaltes. Genauer gesagt erzielen Landwirte, die die Bt-Baumwolltechnologie annehmen, um 50 bis 60 Kilogramm pro Morgen höhere Erträge und das durchschnittliche Einkommen der Haushalte ist um 16.500 bis 17.000 Rupien höher. Der Pestizidverbrauch der annehmenden Haushalte ist um 0,62 bis 0,68 Liter pro Morgen niedriger und die Wahrscheinlichkeit der annehmenden Haushalte, arm zu sein, ist im Vergleich zu nicht annehmenden Haushalten um etwa 13,5% bis 14,3% niedriger. Die Ergebnisse für die verschiedenen Betriebsgrößen zeigen, dass die neue Technologie sowohl auf Klein-, Mittel- und Großbetriebe günstige Auswirkungen hat, wobei Bt-Baumwolle besonders in Kleinbetrieben dazu beiträgt, die Armut zu reduzieren. Diese Ergebnisse stimmen mit den bisherigen Studien überein, die ebenfalls die Annahme von Bt-Baumwolle und die Auswirkungsbewertung in verschiedenen Ländern wie China, Indien oder Argentinien untersucht haben.

Die Ergebnisse bezüglich des Einflusses der Bodenrechte auf die Entscheidung der Landwirte, in Bodenverbesserungsmaßnahmen und den Wirkungsgrad zu investieren, weisen darauf hin, dass Landwirte mit sicheren Bodenrechten stärker in Bodenverbesserungsmaßnahmen, wie z.B. Stalldung, Mineraldünger und

Hülsenfrüchte, investieren. Die Werte belegen, dass vom Besitzer bestelltes Land die höchsten technischen, allokativen und wirtschaftlichen Leistungserträge aufweist. Genauer gesagt betragen die allokativen Wirkungsgrade der vom Besitzer bestellten Böden, der Böden von Pächtern mit fester Miete und von Farmpächtern 92%, 85% und 82% und die entsprechenden Zahlen für den technischen Wirkungsgrad sind 86%, 80% beziehungsweise 77%. Die wirtschaftlichen Wirkungsgrade für die von Besitzer bestellten Böden, die Böden von Pächtern mit fester Miete und von Farmpächtern betragen 78%, 68% beziehungsweise 62%. Die Ergebnisse deuten darauf hin, dass Besitzer technisch, allokativ und wirtschaftlich gesehen effizienter sind, als Pächter mit fester Miete oder Farmpächter, wobei Pächter mit fester Miete wiederum effizienter sind, als Farmpächter.

Die Ergebnisse für die Marktteilnahme der Landwirte zeigen, dass die Marktteilnahme durch die Ressourcen des Landwirts und das Vermögen des Haushaltes beeinflusst wird. Ressourcenstarke Landwirte haben im Vergleich zu ressourcenschwächeren Landwirten einen leichteren Marktzugang, da reichere Haushalte für den Baumwollverkauf weitere Strecken zurück legen können und sie sind darüber hinaus fähig, größere Mengen an Baumwolle zu verkaufen. Die Nettoerträge sind signifikant positiv für Landwirte, die ihre Baumwolle auf dem Markt verkaufen im Vergleich zu Landwirten, die ihre Baumwolle ab Hof verkaufen.

Die vorliegende Studie hat bedeutende Auswirkungen auf die Politik, da die Annahme von Bt-Baumwolle einen signifikant positiven Einfluss auf die Baumwollerträge, das Haushaltseinkommen und die Armutsreduktion, sowie einen signifikant negativen Einfluss auf die Pestizidnachfrage hat. Besonders die Förderung neuer Agrartechnologie in Kleinbetrieben kann ihre Produktivität und ihr Einkommen erhöhen und die Armut dieser Haushalte reduzieren. Maßnahmen in diese Richtung beinhalten die Verbesserung des Zugangs der Baumwollproduzenten zu Information, um die Unsicherheit gegenüber neuen Technologien zu verringern, und zu Krediten, um Liquidiätseinschränkungen zu überwinden. Darüber hinaus sollten die Bildung und die Infrastruktur der Baumwollproduzenten verbessert und verbesserte Beratungsdienste angeboten werden, um sie bei der Annahme der Bt-Baumwolltechnologie zu unterstützen. Da Besitzer technisch, allokativ und wirtschaftlich effizienter sind als Pächter, sollten Pächter durch Bodenreformen mit mehr Bodenrechten ausgestattet werden. Dies wird Kleinbetriebe ermutigen, in Bodenverbesserungsmaßnahmen zu investieren, um höhere technische, allokative und wirtschaftliche Wirkungsgrade zu erreichen, wodurch die Baumwollproduktivität auf nationaler Ebene gesteigert werden kann. Die Ergebnisse für das Baumwollmarketing weisen darauf hin, dass wohlhabendere Haushalte momentan leichteren Zugang zu Märkten haben. Am Markt

Teil nehmende Landwirte haben höhere Nettoerträge im Vergleich zu Landwirten, die ihre Baumwolle ab Hof verkaufen. Kleinbauern können mit dem Markt verbunden werden, indem in Humankapital investiert, die dörfliche Infrastruktur verbessert und Kreditprogramme für Kleinbauern vereinfacht werden.

Chapter 1

Introduction

1. Problem Setting and Motivation

Cotton occupies the main position in Pakistan's economy, since two thirds of the country export earnings are from cotton and cotton products. In Pakistan, more than 67% of the population lives in rural areas, which are directly or indirectly dependent on agricultural activities for their livelihood. Cotton production supports millions of farm families in Pakistan. Genetically modified cotton was first introduced in 1996 in USA and Australia, since then many countries have commercialized the cultivation of Bt cotton such as China, India, USA, Argentina, Australia, South Africa, Mexico, Columbia and Indonesia. As a result, the area devoted to Bt cotton has increased from 1.9 million acres in 1996 to more than 25 million acres in 2008. Although a large number of studies have been carried out in cotton producing countries regarding the adoption and impact of Bt cotton technology, past studies have mostly focused on cotton yields and pesticide demand (see e. g. Crost et al., 2007; Huang et al., 2002; Qaim and Zilberman, 2003). The most important aspect that is missing in the past literature is the Bt cotton impact on household poverty. The second important aspect that is missing in the literature is that only a couple of studies have taken into account the selectivity bias problem and no study has employed the propensity score matching approach in the past, which is quite new in the growing literature. In Pakistan, Bt cotton has only recently been introduced. The present study is one of very few studies that explicitly analyzed household poverty effects of genetically modified crops and the first impact assessment of Bt cotton in Pakistan.

Past literature on land rights has focused different countries and their influence on investment in land improvement measures. In Pakistan, only a couple of studies has been carried out regarding land rights' influence on farmers' decision to invest in land improvement measures but no study has related the improvement in soil capital to the household efficiency level. Due to highly skewed land ownership, one third of the farmers are tenant farmers in Pakistan. Tenant farmers receive less institutional support and have fewer resources. Due to higher tenancy rates in Pakistan, the cotton yield per hectare is low and is only 781 kg, while in other cotton producing countries it is much higher, e.g. Israel 1,818 kg, Australia 1,802 kg, Syria 1,571 kg, Mexico 1,312 kg, Turkey 1,289 kg, Greece 1081 kg, USA 951 kg and Egypt 939 kg (International Cotton Advisory Committee, 2003). In Pakistan, the per hectare productivity of cotton is low and the cost of production is high. As a result, cotton is also facing the danger of replacement by competing crops like sugarcane and rice (Pakistan Times, 2006). In the present study, land rights' influence on farmers' decision to invest in land improvement measures and its impact on technical, allocative and economic efficiency levels of cotton farmers is estimated, which received little attention in the past.

There was not much attention in the past on cotton farmers' market participation. Generally, a little literature exists on farmers' market participation in developing countries, specifically in Pakistan. In Pakistan, cotton farmers' market participation besides other factors is influenced by the high transaction costs and liquidity constraints. Since cotton is a high input demanding crop, small and medium scale farmers face liquidity constraints. In Pakistan, formal credit sources has mostly failed to meet the demand of the cotton farmers, so farmers mostly turn to informal credit sources, i.e. local traders (commission agent), who interlock the supply of credit with the provision of output. In the present study, cotton farmers' market participation and determinants of decision making are studied by employing different sample selection models. The current study is focusing on three important aspects of cotton production and marketing in Pakistan, i.e. adoption and impact of genetically modified cotton technology, land rights' influence on farmers' decision to invest in land improvement measures and cotton farmers' access to markets. These three aspects have received less attention in the past, particularly in the context of production and marketing of cotton in Pakistan.

2. Objectives and Hypotheses

Objectives

The overall objective of this dissertation is to study the production and marketing system of cotton in Pakistan. The specific objectives of the study are

1. To estimate the impact of Bt cotton adoption on cotton yields, household income, pesticide demand and poverty status among cotton farmers in Pakistan.

2. To compare the Bt cotton adoption and impact evaluation among different farming categories i.e. small, medium and large scale farmers.
3. To estimate the land rights influence on farmers' decision to invest in land improvement measures and technical, allocative and economic efficiency levels.
4. To study the impact of transaction costs and liquidity constraints on cotton farmers' market participation.
5. Based on the findings, to suggest policy recommendations to improve the cotton production and marketing in Pakistan.

Hypotheses

The following hypotheses will be tested in the study.
1. Genetically modified cotton adoption has a positive impact on the livelihood of cotton farmers and the overall household welfare.
2. Genetically modified cotton adoption has a positive and significant impact among all farming categories, i.e. small, medium and large scale farmers and particularly among small scale farmers.
3. Land rights have a positive impact on farmers' decision to invest in land improvement measures; owners having secured land rights invest more in land improvement measures (farm yard manure, mineral fertilizer and leguminous crops) compared to tenants (both sharecroppers and fixed renters).
4. Farmers having secured land rights are technically, allocatively and economically more efficient compared to farmers having no secured land rights, i.e. owners have higher efficiency levels in comparison to tenants (fixed renters and sharecroppers).
5. Cotton farmers' market participation is influenced by the high transaction costs and liquidity constraints. The farmers having more resources have easy access to markets compared to resource poor farmers.

3. Significance of Study

The present study is important for all the stakeholders involved in the production and marketing of cotton, as it addresses three important aspects of cotton production and marketing in Pakistan simultaneously, i.e. the adoption and impact of the Bt cotton technology; land rights' influence on farmers' decision to invest in land improvement measures and efficiency level and factors influencing cotton farmers' market participation. The current study is the first Bt cotton adoption and impact evaluation study in Pakistan. Bt cotton has only recently been introduced in Pakistan and currently more than 60% of the cotton farmers are planting Bt cotton varieties, covering more than 75% of the cotton producing area, hence the estimation of the impact of the new technology was important. The current study is also in line with the efforts of the government of Pakistan. Since the government has recently introduced a plan titled "Cotton vision 2015 targets" after taking into account the future prospects for a sustained growth in the cotton sector and the possible improvements in the quality of raw cotton. The targets of the plan include considerable increase in cotton yield per hectare, mill consumption of cotton to 20.1 million bales, exportable cotton surplus to 0.6 million bales and improved yarn recovery rate to 92% from current average of 84%. The plan has been designed to achieve higher production of clean cotton to obtain advantages of assured supply of cleaner, uniform, graded and contamination free cotton to the domestic textile industry. It may also be helpful to get a higher recovery rate, hence more yarn would improve the reputation of Pakistan's cotton and its products in the world market and substantial foreign exchange would be earned through better unit values.

Only a couple of studies in Pakistan have focused on the land rights' influence on farmers' decision to invest in land improvement measures. But no study has related the influence of land rights and investment in land improvement measures to the household's efficiency level. The current study is focusing on this important aspect, since one third of the farmers are tenant farmers in Pakistan having fewer land rights and less resources. Besides estimating the land rights' influence on farmers' decision to invest in land improvement measures, the investment in land improvement measures is related to farmers' technical, allocative and economic efficiency levels, which is mostly not addressed in the previous literature.

The literature on farmers' market participation has received little attention in the past in developing countries (Fafchamps and Hill, 2005). Specifically in Pakistan, there exists little literature on cotton farmers' access to the market and the determinants of the cotton farmers' market participation.

4. Scope and Limitation of Study

The present study is broad based, since it is focusing on three different areas simultaneously, i.e. the adoption and impact of Bt cotton technology; land rights influence on farmers' decision to invest in land improvement measures and efficiency level; impact of transaction costs and liquidity constraints on cotton farmer market participation. The study findings are important for all the stakeholders involved in production and marketing of cotton in Pakistan, i.e. policy makers, researchers, extensionists and cotton farmers. Since the present study is the first Bt cotton adoption and impact evaluation study in Pakistan, study findings have extreme significance for policy makers regarding the future adoption of Bt cotton technology in Pakistan.

Land rights' influence on farmers' decision to invest in land improvement measures and efficiency levels has important policy implications for policy makers. Land reforms are needed to be carried out in Pakistan, as this will be helpful in increasing the farmers' efficiency levels and the overall household productivity at the micro level and will be helpful in increasing the national productivity at the macro level.

Farmers' access to the market will provide information about the determinants of farmers' market participation decision making especially with reference to liquidity constraints and transaction costs. Due to time and resource constraints, the study is limited to one province (Punjab) and the seven highest cotton producing districts only. Cross sectional data was employed in the current study; although panel data provide more useful information regarding efficiency measurement.

5. Organization of the Dissertation

The dissertation is organized as follows: chapter two provides background information about production and marketing of cotton in Pakistan. Chapter three is a paper on adoption of genetically modified cotton and poverty reduction in Pakistan. Chapter four is a paper on land rights influence on farmers' decision to invest in land improvement measures and efficiency level. Chapter five is a paper on cotton farmers' access to markets in Pakistan. In chapter six the concluding remarks and policy recommendations are presented along with directions for future research.

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Chapter 2

Production and Marketing of Cotton in Pakistan

1. Background

1.1 Pakistan Geographic Profile

The geography of Pakistan is a profound blend of landscapes varying from plains to deserts, forests, hills and plateaus ranging from the coastal areas of the Arabian sea in the South to high mountain ranges of the sub-continental North: the Himalayas, the Karakorams and the Hindu Kush. The vast and rich irrigated plains of the Indus basin covering vast tracts of the Punjab and Sindh, the deserts of Cholistan (Punjab) and Thar (Sindh), the inter-mountain valleys of the North West Frontier Province (NWFP)[1] and the awe-inspiring rugged plateaus of Balochistan and the meeting point of the Himalayas, the Hindu Kush and the Karakoram in the Northern Areas (NA) are some of the most varied features of the country's landscape (ICIMOD, 1998).

Geographically, Pakistan lies between 24^0 and 37^0 N latitude and 61^0 and 75^0 E longitude. It is bordered by China in the North, Arabian sea in the South, Iran in the West, Afghanistan in the North-West and India in the East (ICIMOD, 1998). Pakistan consists of four provinces (Punjab, Sindh, Balochistan and NWFP) including Azad Jammu and Kashmir (AJK) and Northern Areas. The population is about 170 million and is growing at a rate of 1.8% annually. Pakistan is the sixth most populous country in the world (Pakistan Encyclopedia, 2009).

The total geographic area of Pakistan is 79.6 million hectares. About 27% of the area is currently under cultivation of which about 80% is irrigated. In this regard, Pakistan has one of the highest proportions of irrigated cropped area in the world. The cultivable waste land amounts to 8.9 million hectares, and offers good possibilities for crop production.

The climate of Pakistan varies with altitude, which in turn affects the type of vegetation. It has some of the world's highest cold areas in the Himalayas and the hottest low

[1] New name of NWFP is Khyber pakhtunkhaw.

areas in the Indus plains with many intermediate ecological zones (ICIMOD, 1998). Pakistan lies in the temperate zone characterized by hot summers and cold winters, and wide variations between extremes of temperature at given locations. The rainfall is seasonal and erratic; the rainfall varies between 50 mm in the South to more than 1500 mm in the North. Pakistan has four seasons: a cool, dry winter from December through February; a hot, dry spring from March through April; the summer rainy season, or Southwest monsoon period, from June through September; and the retreating monsoon period of October and November. The onset and duration of these seasons vary somewhat according to location (Pakistan Encyclopedia, 2009). The climatic conditions are very suitable for economic cultivation, production and growth of all types of crops, fruits, nuts and vegetables that are produced and grown in any part of the world.

1.2 Pakistan Agricultural Sector Brief

Pakistan is an agricultural country, since agriculture is the backbone of Pakistan's economy. Agriculture contributes about 21.8% to the GDP and employs 44.7% of the workforce. More than two-third of Pakistan's population lives in rural areas and their livelihood continue to revolve around agriculture and allied activities (Economic Survey of Pakistan, 2008-09). In foreign trade, agriculture dominates through exports of raw products such as rice and cotton. Moreover, semi-processed and processed products such as cotton yarn, cloth, carpets and leather products, the share of primary commodities and processed and semi-processed products constituted almost 60% of the total exports. There have been some structural changes over time, but the contribution of agro-based products has more or less sustained its position. Agriculture is the hub of economic activity in Pakistan. It lays the foundation for economic development and growth of the economy (Government of Pakistan, 2003). The importance of agriculture to the economy is seen in three ways: first, it provides food to the consumers and fibers for domestic industry; second, it is a source of foreign exchange earnings; and third, it provides a market for industrial goods.

The most important crops grown in Pakistan are cotton, wheat, rice, sugarcane, maize, fruits and vegetables which together account for more than 75% of the value of total crop output (Economic Survey of Pakistan, 2005-06). According to the Food and Agriculture Organization (2005), Pakistan is the second largest producer of chickpea, the fourth largest producer of apricot, cotton and sugarcane, the fifth largest producer of milk and onion, the sixth largest producer of date palm, the seventh largest producer of mango, the ninth largest producer of wheat and the tenth largest producer of oranges in the world. Overall, Pakistan is ranked twentieth in the world regarding farm output (FAO, 2005).

There are two principal crop seasons in Pakistan, namely *"Kharif"*, sowing season of which begins in April-June and harvesting during October-December; and the *"Rabi"* which begins in October-December and ends in April-May. Rice, sugarcane, cotton, maize, mong, mash, pigeon pea and sorghum are *"Kharif"* crops while wheat, gram, lentil (masoor), tobacco, rapeseed, barely and mustard are *"Rabi"* crops (Economic Survey of Pakistan, 2008-09).

1.3 Cotton Production in Pakistan

Cotton is the largest revenue earning non-food crop produced in the world. Its production and processing provides some or all of the cash income to over 250 million people worldwide, including almost 7% of the available labor force in developing countries. Cotton is grown in approximately 70 countries of the world, but the top 10 cotton producing countries share 85% of the total world production. These countries are Australia, Brazil, China, Greece, India, Pakistan, Syria, Turkey, USA and Uzbekistan (International Cotton Advisory Committee, 2003). The world cotton production is projected to decline by about 10% in 2008-09, to 108.8 million bales[2], mainly due to the decline in world cotton areas caused by increased competition from alternative crops. Significant portions of cotton area were diverted to grains and oilseed production due to more attractive prices than cotton. The world yield is also estimated slightly lower mainly due to unfavorable weather. The world yield is projected down to 763 kg per hectare from the record of 788 kg per hectare reached in 2007-08, and this is the second consecutive season of decline in world cotton yield (Economic Survey of Pakistan, 2008-09).

Pakistan is the ancient home of cotton cultivation, since in Indus valley civilization (present day Pakistan), the cotton cultivation was first carried out (FAO, 1999). Currently, Pakistan is the fourth largest cotton producer worldwide, whereas regarding the yield per hectare Pakistan is ranked 13th in the world. Pakistan is also the third largest exporter of raw cotton, the fourth largest consumer of cotton, and the largest exporter of cotton yarn. In Pakistan about 1.3 million farmers (out of total 5 million)

[2] One cotton bale contains 480 pounds (218 kgs) of cotton.

cultivate cotton covering 3 million hectares and 15% of the cultivable area in the country. Cotton and cotton products contribute about 10% to GDP and 60-65% to the foreign exchange earnings of the country (Government of Pakistan, 2006). Taken as a whole, between 30-40% of the cotton ends up as domestic consumption of final products. The remaining is exported as raw cotton, yarn, cloth, and garments. Pakistan produces about 8 million cotton bales and Pakistan's share in the total world cotton production is 8%. Due to its importance cotton is also known as "white gold" (Pakistan.com, 2007).

Cotton is the sole source of survival for millions of farm families in Pakistan because cotton is an important cash crop for small holders, a major source of employment for farmers and workers in textile industries, and also a major source of foreign exchange (exports of raw cotton, cotton products and byproducts). The strategic problems the industry is faced with at present are rising costs of inputs, declining yield (area, production and yield of cotton in Pakistan is given in appendix A-1) and quality due to weakness in varietals' maintenance, water logging and salinity problems in irrigated plantations (International Cotton Advisory Committee, 2006).

Cotton production supports Pakistan's textile sector, comprising about 400 textile mills, 7 million spindles, 27,000 looms in the mill sector (including 15,000 shuttle looms), over 250,000 looms in the non-mill sector, 700 knitwear units, 4,000 garments units (with 200,000 sewing machines), 650 dyeing and finishing units (with finishing capacity of 1,150 million square meters per year), nearly 1,000 ginneries, 300 oil expellers, and 15,000 to 20,000 indigenous, small scale oil expellers (kohlus). Cotton by any measure is Pakistan's most important economic sector (Banuri, 1998). The rate of economic growth is quite closely correlated with the fate of the cotton crop. A bigger crop means a larger volume of exports (both raw and processed products), subsidy to the textile sector, which leads to higher aggregate demand, higher employment, larger fiscal inflows and less pressure on the balance of payment (Banuri, 1998). The reasons for the decline in cotton production are the shortage of irrigation water, less use of fertilizer, attack of cotton leaf curl virus (CLCV), mealy bug and white fly (Economic Survey of Pakistan, 2008-09).

1.4 Genetically Modified Cotton (Bt Cotton) Prospects

Agricultural biotechnology is identified as a technology that could make a significant contribution to the reduction in the world hunger through increased crop yields and higher incomes for farmers, particularly in developing countries. Genetically modified crops were first commercially introduced in USA and Australia. However, as pointed out by Huang et al. (2002a), the only significant way biotechnology has contributed to the well-being of the poor so far is through higher incomes from the production of genetically modified cotton. Genetically modified cotton has been commercialized in many cotton producing countries like China, USA, India, Argentina, Australia, South Africa, Mexico, Columbia and Indonesia. Because of the wide range of insects that attack cotton, the crop has been identified as the largest worldwide consumer of insecticide. Although cotton accounts for about 2.4% of total acreage cultivated globally, estimates suggest that it consumes over 25% of pesticides (Krattiger, 1997). Hence, production of the crop is often associated with negative externalities. Countries that have introduced *Bacillus thuringiensis* (Bt) cotton have therefore derived benefits through increased yields and declining production costs from reduced application of pesticides (Thirtle et al., 2003; Shankar and Thirtle, 2005; Frisvold et al., 2006; Subramanian and Qaim, 2009).

Although the broader impact of Bt cotton, particularly the long-term environmental implications of the technology, still remains controversial, the positive yield and income effects have contributed to the widespread diffusion of the technology over the last couple of years (Rao, 2007 a, b). At the global level, the area devoted to Bt cotton has increased from 1.9 million acres in 1996 to 25 million acres in 2008 (Clive, 2008). Available evidence shows that the Bt cotton-sown area in China reached 3.7 million hectares in 2004, which comprised more than 40% of the total Bt cotton in the world (Qiao et al., 2007). The proportion of Bt cotton in the total world production is currently about 30% and is projected to exceed the 40% mark by 2010 (Rao, 2007 a, b).

In Pakistan, the Ministry of Food and Agriculture (MINFA) has been working on a two pronged strategy, i.e. developing the technology through indigenous capabilities as well as inviting the multi-national companies to bring in the latest cotton production and protection technologies to enhance the cotton production in the country. In this respect, a *letter of intent* (LoI) and *memorandum of understanding* (MoU) have been signed with the Monsanto company for introduction of latest technology (bollgard-II) in the country to maximize cotton production. The National Biosafety Committee (NBC) of Ministry of Environment has also authorized biosafety clearance to eight cotton varieties with bollard-1 trait (Economic Survey of Pakistan, 2008-09).

Although the Bt cotton technology has not yet been officially commercialized in Pakistan, more than 60% of the cotton farmers are already planting these new hybrids, covering more than 75% of the cotton producing area (Pakistan Central Cotton Committee (2008). The seeds are mainly smuggled into Pakistan from India, and the farmers normally obtain them from Punjab and Sindh provinces, where cotton is largely cultivated (Sharma, 2009).

Particularly in a developing country like Pakistan, information on the impact of adoption of new technologies on the welfare of farm households is quite crucial to understanding how policy interventions can help reducing poverty among farm households.

1.5 Land Tenure and Land Reforms in Pakistan

As in other parts of the developing world, access to land, as well as the security of land tenure contracts determines the social status and the economic well-being of the members of the rural society in Pakistan to a large extent (Haider and Kuhnen, 1974). After independence in 1947, the distribution of land ownership was highly skewed, with less than 1% of the farmers holding more than 25% of the total agricultural land. At the other extreme, about 65% of the farmers held some 15% of the farmland in holdings of about two hectares or less. The unequal distribution of land contributed to tenancy arrangements such as sharecropping and fixed-rent contracts. Evidence shows that more than 50% of the total farm land is cultivated by tenants having no secured or transfer rights (Pakistan Agriculture, 1995). In addition, one-third of the farmers are tenant farmers, who cultivate the land on sharecropping and fixed rent contracts (Jacoby and Mansuri, 2009).

The unequal distribution of land in the country resulted in two main land reform attempts. The first attempt was made in 1959, when land reforms fixed the ceiling for private ownership of land at 500 acres for irrigated and 1,000 acres for un-irrigated land. A major problem of this reform was that ceilings were fixed in terms of individuals rather than families, such that families can still own a large number of acres of land. A second attempt was therefore made in 1972, in which the ownership ceiling was reduced to 150 acres of irrigated and 300 acres of un-irrigated land. Although the reforms appeared good on paper, the implementation was quite poor. Less than 0.9 million acres of land was acquired for redistribution, which was about one-third of the land resumed under the 1959 land reforms. Moreover, the ceilings remained in terms of individuals rather than families. Hence, a number of large land owners still managed to keep their holdings within an extended joint family framework, while giving away only marginal and less productive lands (Rao, 2007). Land ownership in the country therefore remained highly concentrated.

The major forms of land tenure arrangements in the country and particularly in the study area are owner-operated with full property rights, fixed-rent and sharecropping contracts. The owner-operated with full rights involves farmers owning and cultivating their own plots. Farmers cultivating these plots have transfer rights, including rights to sell the plots. The fixed-rent contracts involve land owners renting out land to tenants[3], a sharecropping contract is an arrangement made between the landlord and the operator, such that part of the output is given to the landlord as compensation for using the land. The sharecropping contract appears to be less risky for the owner, since offering a share rental contract enables the landlord to direct the tenant's choice of project towards the kind that the landlord prefers (Basu, 1992). In some cases, the tenant gets one-fourth, one-sixth, or only one-eighth of the output, depending on the terms of agreement and contribution made in inputs. Normally, the fixed-rent contracts are informal and tend to vary between one and three cropping seasons, although they can prolong for several years, depending on the mutual understanding between the owner and the tenant (Jacoby and Mansuri, 2008).

1.6 Cotton Marketing System in Pakistan

Efficient marketing plays a crucial role in the process of economic development (Barrett and Emelly, 2005; Gideon et al. 2007; Kleih, 1999). In developing countries, the marketing system is mainly confronted with multiple problems like high transaction costs, poor physical and institutional infrastructure, lack of market information and inadequate markets (Jones, 1996). Regarding cotton marketing decision making (market or farm gate) in Pakistan, the household's financial condition plays a crucial role. If the farmer is financially well-off, he mostly neither needs credit from informal sources nor has to buy inputs on credit. But the majority of cotton producers need credit during cotton season to meet the high input demand of the cotton crop or to buy inputs on credit from a local trader (commission agent). In return, they are bound to sell cotton to that particular person from whom they have taken the credit[4], although there exists the formal credit programme in the cotton growing areas of Pakistan.

[3] The amount of rent varies depending on the soil fertility, location of land, irrigation source and the previous dealing etc.
[4] The interlocking of input supply, credit and crop marketing are the common features of the marketing system in many developing Asian countries including Pakistan (Smith et al., 1999).

Unfortunately, the formal credit programme is not very effective since the procedure is lengthy; the mark up rate is high and also not in favour of small farmers[5]. Landless farmers are deprived of the credit facility from the formal sources due to no own land holding[6]. Because of these procedural and institutional problems the farmers turn to informal credit sources i.e. local traders (commission agent) since they provide ready credit[7]. Such systems are distinct from those where crop marketing, input supply and credit are provided by specialist providers. In developing countries there are major obstacles to the exclusive provision of commercial agricultural services by specialists, due to inherent risk, high transaction costs and weakness in the formal institutional environment; including both means for contract enforcement and property rights, which are important in relation to entitlement.

Commission agents or traders usually operate year round, buying cotton in the winter and wheat in the summer season. They sell cotton to ginning factories, while wheat is either sold to the food department or delivered onto the free market which exists in parallel with the government procurement system. In addition, some growers' mostly larger ones sell their cotton directly to the cotton ginners (Smith et al., 1999). Ginning factories or ginners also provide seasonal credit, mostly to commission agent or traders but in some cases also to growers. The credit is usually interest-free and provided on the condition that the borrower supplies the ginner with a pre-agreed quantity of seed cotton at harvest time (Smith et al., 1999).

A harmonized cotton marketing and pricing system in Pakistan has been lacking and both the seed cotton and lint cotton are priced mostly on the basis of subjective assessment, such as the variety or the station. There is no written contract for buying and selling operations (PCCC, 2004). The importance of farmers associations and cooperatives can not be ignored, but they mostly exist in small numbers and are handicapped by low quality due to inexperienced management, thus not contributing to farmers in a benefiting way (IFAD, 2007).

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[5] In most cases only the wealthier and more influential farmers are able to gain access to loans from formal sources.
[6] The sharecropping or landless households gain even less access to formal sector credit (Smith et al. 1999).
[7] Traders frequently act as moneylenders and input suppliers as well as providing crop marketing services (Smith et al. 1999).

2. Description of Study Area

The present study was carried out in the Punjab province of Pakistan, which is the most populous province with almost 60% of the country population living there. The name Punjab literally translates from the Persian words *Panj* meaning five and *Ab* meaning water. Thus Punjab can be translated as five waters- and hence the land of the five rivers, referring to the *Jhelum*, *Chenab*, *Ravi*, *Beas* and *Sutlej* (Pakistan Encyclopedia, 2009).

The province is mainly a fertile region along the river valleys, while sparse deserts can be found near the border with Balochistan province and India. The region contains the Thal and Cholistan deserts. The landscape is amongst the most heavily irrigated on earth and canals can be found throughout the province. Weather extremes are notable from the hot and barren South to the cool hills of the North. The foothills of the Himalayas are found in the extreme North as well.

Most areas in Punjab experience fairly cool winters, often accompanied by rain. By mid-February the temperature begins to rise; spring time weather continues until mid-April, when the summer heat sets in. The onset of the Southwest monsoon is anticipated to reach Punjab by June. Despite its dry climate, extensive irrigation makes it a rich agricultural region. Its canal-irrigation system (established by the British) is the largest in the world. Wheat is the main food crop, while cotton and rice are important cash crops that contribute substantially to the national exchequer. Other crops include sugarcane, millet, corn, oilseeds, pulses, fruits and vegetables. Livestock and poultry production also contribute substantially to Pakistan agriculture.

Punjab contributes about 68% to the annual food grain production in the country, about 51 million acres (210,000 km^2) are cultivated and another 9.1 million acres (36,600 km^2) are lying as cultivable waste in different parts of the province. Attaining self-sufficiency in agriculture has shifted the focus of the strategies towards small and medium farming, stress on rain fed areas, farm-to-market roads, electrification for tube-wells and control of water logging and salinity.

2.1 Sampling Procedure

The data was collected with a survey of farmers from the Punjab province. In Pakistan, cotton is mainly produced in two provinces i.e. Punjab and Sindh province. More than 80% of the cotton of Pakistan is produced in the Punjab province[8]. Seven highest cotton producing districts were selected from the province of Punjab. A stratified random sampling technique was employed to select the farmers in the districts of Bahawalpur, Bahawalnagar, Vehari, Khanewal, Lodhran, Multan and Rahim Yar Khan.

$$S_i = \frac{x_i}{X} N \qquad (1)$$

In equation (1), S_i represents the stratified random sampling to be drawn from each stratum (district *i*), x_i represents the area under cotton in district *i*. X represent the total area under cotton in the sampling frame districts i.e. Bahawalpur, Bahawalnagar, Vehari, Khanewal, Lodhran, Multan and Rahim Yar Khan. *N* is the total sample size to be drawn from all districts i.e. 325 cotton producers.

As table 1 indicates, the districts were further divided into sub-districts (tehsils) and villages and within villages the selection of farmers was made at random. From each household only one farmer was interviewed. The survey was conducted through questionnaire interviews, which took place between August and December 2007.

[8] About 99% of the cotton production in Pakistan takes place in the Punjab and Sindh provinces. Farming structures for cotton production are similar in Punjab and Sindh provinces. Environmental and climatic conditions, particularly water constraints, in other provinces are not suitable for cotton production.

Table 1: District wise area and production of cotton and number of farmers interviewed from each district

District	Area (in 1000 hectares)	Production (in 1000 bales)	Sub-districts (number)	Villages (number)	Farmers (number)	Percentage
Rahim Yar Khan	308.0	1612.9	4	22	67	20.6
Bahawalpur	281.7	1364.6	4	18	58	17.8
Vehari	239.6	1106.9	3	20	50	15.4
Bahawalnagar	212.1	967.6	5	14	32	9.8
Lodhran	206.8	1077.6	3	19	56	17.2
Khanewal	195.4	899.7	3	16	42	12.9
Multan	193.8	858.6	2	6	20	6.3
Total	1636.7	7887.9	24	115	325	100

Source: Agricultural statistics of Pakistan 2006-07 & own calculations.

Figure 1: Map of Pakistan

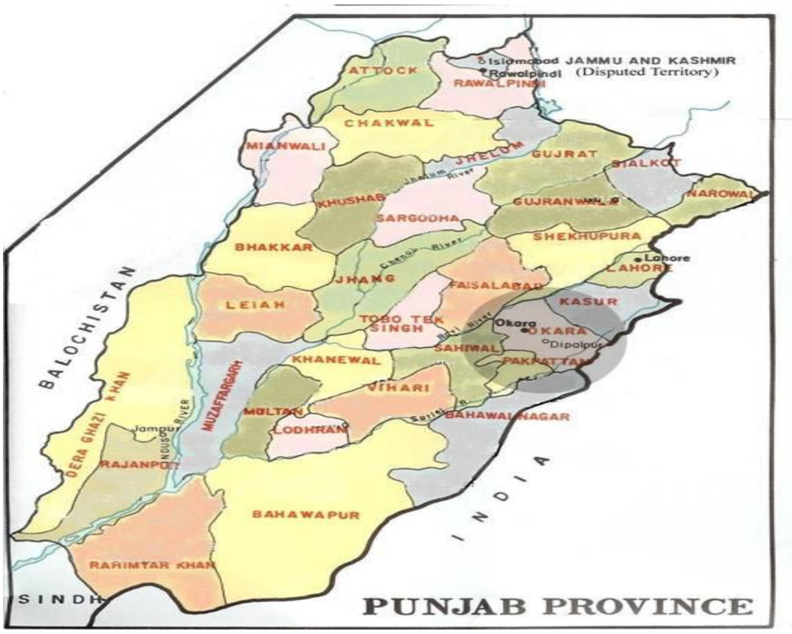

Figure 2: Map of the Punjab Province.

Figure 1 presents the map of Pakistan showing four provinces, i.e. Punjab, Sindh, NWFP, Balochistan and Northern Areas including Azad Jammu and Kashmir.

Figure 2 presents the map of the Punjab province. The area surveyed for data collection purposes lies in the South of the Punjab province consisting of the seven highest cotton producing districts, i.e. Bahawalpur, Bahawalnagar, Vehari, Lodhran, Khanewal, Multan and Rahim Yar Khan.

2.2 Data Collection Tool

A comprehensive questionnaire was prepared as data collection tool (questionnaire attached in appendix A). Detailed information was collected regarding village infrastructure, farmer's socioeconomic characteristics, assets of the farmer, cotton production practices, inputs application, varieties sown, cotton yield, cotton marketing information, constraints in production and marketing of cotton, questions regarding institutional support and access to various facilities were also included in the questionnaire. Before starting the formal survey, the pre-testing of the questionnaire was carried out and the questionnaire was modified in the light of pre-testing results.

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Appendix

Table A-1: Area, production and yield of cotton in Pakistan

Year	Area		Production		Yield	
	(000 hectares)	Change (%)	(000 bales)	Change (%)	(Kg/hec)	Change (%)
2003-04	2989	7.0	10048	-1.6	572	-8.0
2004-05	3193	6.8	14265	42.0	760	32.9
2005-06	3103	-3.0	13019	-8.7	714	-10.3
2006-07	3075	-0.9	12856	-1.2	711	-0.4
2007-08	3054	-0.6	11655	-9.4	649	-8.7
2008-09 (P)	2820	-7.7	11819	1.1	713	9.9

Source: Economic Survey of Pakistan 2008-09.
Note: P=Provisional (July - March).

Chapter 3

Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan

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Chapter 3

Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan

Abstract

This article employs a propensity score-matching approach to examine the direct effects of adoption of *Bacillus thuringiensis* (Bt) cotton on yields, pesticide demand, household income and poverty, using cross sectional data from a survey of farmers in the Punjab province of Pakistan. Generally, the findings reveal that adoption of the new technology exerts a positive and significant impact on cotton yields, household income and poverty reduction, and a negative effect on the use of pesticides. The positive and the significant impact of the technology on yields and household income is consistent with the potential role of new agricultural technology in directly reducing rural poverty through increased farm household income.

Keywords: *Agricultural biotechnology; Bt cotton; impact assessment; propensity score matching.*

JEL classification: *I*32, *Q*16

1. Introduction

Agriculture biotechnology is identified as a technology that could make a significant contribution to the reduction in world hunger, through increased crop yields and higher incomes for farmers, particularly in developing countries. However, as pointed out by Huang et al. (2002a), the only significant way that biotechnology has contributed to the well-being of the poor so far is through higher incomes from the production of genetically modified cotton. Because of the wide range of insects that attack cotton, the crop has been identified as the largest worldwide consumer of insecticide. Although cotton accounts for about 2.4% of total acreage cultivated globally, estimates suggest that it consumes over 25% of pesticides (Krattiger, 1997). Hence, production of the crop is often associated with negative externalities. Countries that have introduced *Bacillus thuringiensis* (Bt) cotton have therefore derived benefits through increased

yields and declining production costs from reduced application of pesticide (Thirtle et al., 2003; Shankar and Thirtle, 2005; Frisvold et al. 2006; Subramanian and Qaim, 2009).
Although the broader impact of Bt cotton, particularly the long-term environmental implications of the technology still remains controversial, the positive yield and income effects have contributed to the widespread diffusion of the technology over the last couple of years (Rao, 2007 a, b). At global level, the area devoted to Bt cotton increased from 1.9 million acres in 1996 to 25 million acres in 2008 (Clive, 2008). Available evidence shows that the Bt cotton-sown area in China reached 3.7 million hectares in 2004, which comprised more than 40% of the total Bt cotton area in the world (Qiao et al., 2007). The proportion of Bt cotton in total world production is currently about 30% and is projected to exceed 40% by the year 2010 (Rao, 2007a, b).

Although Bt cotton technology has not yet been officially commercialized in Pakistan, more than 60% of the cotton farmers are already planting these new hybrids (Pakistan Central Cotton Committee, PCCC, 2008). The seeds are mainly smuggled into Pakistan from India, and the farmers normally obtain them from the Punjab and Sindh provinces, where cotton is largely cultivated, about 75% of the land under cotton cultivation was devoted to Bt cotton in 2008 (Sharma, 2009).

As mentioned above, most of the impact studies conducted have examined the effects of the technology on yields and pesticide application. In a recent study, Subramanian and Qaim (2009) employ a social accounting matrix to analyse the village-wide effects of the technology in India. In this study we contribute to the debate on the benefits of Bt cotton by employing a non-experimental evaluation strategy to assess the impact of the technology on the welfare of a sample of farm households from the Punjab province in Pakistan, the largest cotton-growing area in the country. The impact of technology on pesticide application and productivity is also examined. Specifically, a propensity score model is employed to control for self selection that normally arises when technology adoption is not randomly assigned and self-selection into adoption occurs. This study is one of the very few studies that explicitly analyse household poverty effects of genetically modified crops and to the best of our knowledge, the first impact assessment of Bt cotton in Pakistan (Qaim et al., 2009).

Particularly in a developing country like Pakistan, information on the impact of adoption of new technologies on the welfare of farm households is quite crucial to understanding how policy interventions can help reduce poverty among farm households. Cotton is an important cash crop in the country, accounting for 8.2% of the value added in agriculture and almost 3.2% of GDP. About two-thirds of the country's export earnings are derived from the crop, while hundreds of ginning factories and textile mills in the country heavily depend on the domestic cotton production (Rao, 2007 a, b). Moreover, a large proportion of the farming population depends on cotton production for their livelihoods, Bt cotton has only recently been introduced into the country, it is already widely, if illegally, used, and the effects can be examined.

The article is structured as follows. Section 2 outlines the conceptual framework and empirical specification for the study. Section 3 provides a description of the data and definition of the variables. The empirical results from the analysis are presented in section 4, followed by concluding remarks in the final section.

2. Conceptual Framework of Technology Adoption

2.1. Technology Choice

Let the adoption of Bt cotton technology be a dichotomous choice, where the new technology is adopted when the net benefits from choosing the technology is greater than not adopting the technology. The difference between the net benefits from adoption and non-adoption may be denoted as *I**, such that *I** > 0 indicates that the net benefits from adoption exceed that of non-adoption. However, *I** is not observable, but can be expressed as a function of observable elements in the following latent variable model

$$I_i^* = \beta Z_i + \mu_i, \qquad I_i = 1[I_i^* > 0] \tag{1}$$

where I_i is a binary indicator variable that equals 1 for household *i* in case of adoption and 0 otherwise, β is a vector of parameters to be estimated, Z_i is a vector of household and plot-level characteristics and μ_i is an error term assumed to be normally distributed.

The probability of adoption of the new technology can be represented as

$$\Pr(I_i = 1) = \Pr(I_i^* > 0) = \Pr(\mu_i < -\beta Z_i) = 1 - F(-\beta Z_i), \tag{2}$$

where F is the cumulative distribution function for μ_i. Different models such as logit or probit normally result from the assumptions that are made on the functional form of *F*. As argued earlier, the adoption of Bt cotton is expected to affect the demand for inputs such as pesticide, as well as yields and net returns. To link the adoption decision with these potential outcomes of adoption, consider a risk neutral farm that maximizes net returns, π, subject to competitive input and output markets and a single-output technology that is quasi-concave in the vector of variable inputs, *W*. This may be expressed as

$$\max \pi = PQ(W, Z) - YW \quad (3)$$

where *P* is the output price and *Q* is the expected output level; *Y* is a column vector of input prices, whereas *W* is a vector of input quantities, and *Z* represents farm-level and household characteristics. The farm net returns can be expressed as a function of technology choice *I*, output price, variable inputs and household characteristics as follows

$$\pi = \pi(I, Y, P, Z) \quad (4)$$

The application of Hotelling's Lemma to equation (3) yields the reduced form equations for input demand and output supply:

$$W = W(I, Y, P, Z) \quad (5)$$

$$Q = Q(I, Y, P, Z) \quad (6)$$

The specifications in equations (4)-(6) show that the choice of technology, input and output prices, as well as farm and household characteristics tend to influence farm net returns, demand for inputs and level of farm output.

2.2 Impact Evaluation Problem

The discussion in the previous section shows that new agricultural technologies can help increase productivity and farm incomes, and as such, improve the welfare of farm households. Although several other reasons can be advanced to explain why agricultural technology may be crucial in improving the welfare of farm household, it is difficult to simply attribute the differences in welfare between adopters and non-adopters of the technology to adoption. In cases where experimental data are gathered through randomisation, information on the counterfactual situation would normally be provided, and as such the problem of causal inference can be resolved. However, when the data available are from a cross-sectional survey, as the one employed in the present study, no information on the counterfactual situation is obtained. An effective way of addressing the problem is to resort to an investigation of the direct effect of technology adoption by looking at the differences in outcomes among farm households (Blundell and Costa Dias, 2000).

Given that the decision of households to adopt or not to adopt the new technology may be associated with the net benefits of adoption, the issue of self-selection is crucial. To show the significance of self-selection, consider a reduced-form relationship between the technology choice and the outcome variable such as

$$R_i = \alpha_0 + \alpha_1 I_i + \alpha_2 Z_i + \varepsilon_i \qquad (7)$$

where R_i represents a vector of outcome variables for household *i*, such as demand for inputs, farm output, net returns and poverty status of the household. As in the previous section, Z_i represents household characteristics and ε_i an error term, with $\varepsilon_i \sim N(0,\sigma)$. The issue of selection bias arises if unobservable factors influence both the error term of the technology choice, μ_i, in equation (1) and the error term of the outcome specification (ε_i), in equation (7), resulting in a correlation of two error terms. When the correlation between the two error terms is greater than zero, OLS regression techniques tend to yield biased estimates. Some authors have employed the Heckman two-step method or similar approaches to address selection bias. However, the two step procedures are completely dependent on the strong assumption that unobserved variables are normally distributed. Another way of controlling for selection bias is to employ instrumental variable approach (IV). A major limitation of the approach is that it normally requires at least one variable in the treatment equation to serve as an instrument in specifying the outcome equation. Finding such instruments remains an arduous task in empirical analyses. Moreover, both OLS and IV procedures tend to impose a linear functional form assumption, implying that the coefficients on the control variables are similar for adopters and non-adopters. As indicated by Jalan and Ravallion (2003); Mendola (2007), this assumption is not likely to hold.

When panel data are available, selection bias can be addressed by the difference in differences matching estimator. Difference-in-difference matching differs from cross-sectional matching in that it allows for temporally invariant differences in outcomes between adopters and non-adopters (Smith and Todd, 2005). Crost et al. (2007) also employed a fixed effects approach to account for selection bias in their analysis of genetically modified crop productivity estimates for Indian cotton farmers.

In the absence of panel data, this study employs statistical matching to address the problem of selection bias. This involves pairing adopters and non-adopters that are similar in terms of their observable characteristics (Dehejia and Wahba, 2002).

When outcomes are independent of assignment to treatment, conditional on pre-treatment covariates, matching methods can yield an unbiased estimate of the treatment impact.

2.3 Propensity Score Method

It follows that the expected treatment effect for the treated population is of primary significance. This effect may be given as

$$\tau|_{I=1} = E(\tau \mid I=1) = E(R_1 \mid I=1) - E(R_0 \mid I=1) \quad (8)$$

where τ is the average treatment effect for the treated (ATT), R_1 denotes the value of the outcome for adopters of the new technology and R_0 is the value of same variable for non-adopters. As noted above, a major problem is that we do not observe $E(R_0 \mid I=1)$. Although the difference $[\tau^e = E(R_1 \mid I=1) - E(R_0 \mid I=0]$ can be estimated, it is potentially biased estimator.

In the absence of experimental data, the propensity score-matching model (PSM) can be employed to account for this sample selection bias (Dehejia and Wahba, 2002). The PSM is defined as the conditional probability that a farmer adopts the new technology, given pre-adoption characteristics (Rosenbaum and Rubin, 1983). To create the condition of a randomized experiment, the PSM employs the unconfoundedness assumption also known as conditional independence assumption (CIA), which implies that once Z is controlled for, technology adoption is random and uncorrelated with the outcome variables[9]. The PSM can be expressed as,

$$p(Z) = \Pr\{I = 1 \mid Z\} = E\{I \mid Z\} \quad (9)$$

where I = {0,1} is the indicator for adoption and Z is the vector of pre-adoption characteristics. The conditional distribution of Z, given p (Z) is similar in both groups of adopters and non-adopters.

Unlike the parametric methods mentioned above, propensity score matching requires no assumption about the functional form in specifying the relationship between outcomes and predictors of outcome. The drawback of the approach is the strong assumption, of unconfoundness. As argued by Smith and Todd (2005), there may be systematic differences between outcomes of adopters and non-adopters even after conditioning because selection is based on unmeasured characteristics. However, Jalan and Ravallion (2003) point out that the assumption is no more restrictive that those of the IV approach employed in cross-sectional data analysis. In a study by Michalopoulos et al. (2004) to assess which non-experimental method provides the most accurate estimates in the absence of random assignment, they conclude that propensity score methods provided a specification check that tended to eliminate biases that were larger than average. On the other hand, the fixed effects model did not consistently improve the results.

2.4. Average treatment effects

After estimating the propensity scores, the average treatment effect for the treated (ATT) can then be estimated as

$$\tau = E\{R_1 - R_0 \mid I = 1\} = E\{E\{R_1 - R_0 \mid I = 1, p(Z)\}\} = E\{E\{R_1 \mid I = 1, p(Z)\} - E\{R_0 \mid I = 0, p(Z)\} \mid I = 0\} \quad (10)$$

Several techniques have been developed to match adopters with non-adopters of similar propensity scores. The most commonly used techniques include nearest neighbour matching (NNM), kernel-based matching (KBM), stratified matching, radius

[9] As pointed out by Imbens and Wooldridge (2009), unconfoundedness implies that we have a sufficiently rich set of predictors for the adoption indicator, contained in the vector of covariates, such that adjusting for differences in these covariates leads to valid estimates of causal effects.

matching and Mahalanobis matching methods[10]. The NNM and KBM methods are employed here.

The NNM involves choosing individuals from the adopters and non-adopters that are closest in terms of propensity scores as matching partners. Several variants of the NNM have been proposed in the literature, including NNM matching 'with replacement' and 'without replacement'. In the former case, an untreated individual can be used more than once as a match, whereas in the latter case it is considered only once[11]. Matching with replacement involves a trade-off between bias and variance (Smith and Todd, 2005). Allowing for replacement increases the average quality of matches but tends to reduce the number of distinct non-adopters observations used to construct the counterfactual mean, thus increasing the variance.

The KBM method is also a non-parametric matching method that uses the weighted average of the outcome variable for all individuals in the group of non adopters to construct the counterfactual outcome, giving more importance to those observations that provide a better match. This weighted average is then compared with the outcome for the group of adopters. The difference between the two terms provides an estimate of the treatment effect for the treated case. A sample average over all adopters is then the estimate of the sample average treatment effect for the treated group. As pointed out by DiNardo and Tobias (2001), the choice of the kernel function for the KBM does not appear to be important. However, Hujer et al. (2004) point out that a proper imposition of the common support condition is quite crucial in employing the KBM, as this helps in avoiding bad matches[12].

It is important to note that a major objective of propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters. The balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case the matched comparison group can be considered as plausible counterfactual (Caliendo and Kopeinig, 2008). Although several versions of

[10] A comprehensive overview of the various matching algorithms is presented in Caliendo and Kopeinig (2008).
[11] Dehejia and Wahba (2002) show in their study that matching without replacement results in many bad matches in the sense that many participants get matched to non-participants with very different propensity scores.
[12] Basically, this involves dropping observations from the adopter group whose *p-score* is higher than the maximum or less than the minimum score of the non-adopters (Leuven and Sianesi, 2003).

balancing tests exist in the literature, the most widely used is the standardized mean differences between treatment and control sample suggested by Rosenbaum and Rubin (1985), who suggest that a standardized difference of greater than 20% should be considered as 'large'. Sianesi (2004) has also suggested a comparison of the pseudo-R^2 obtained from the analysis before and after matching the samples. The pseudo-R^2 should be lower after matching, to ensure that there are no systematic differences in the distribution of the covariates between the two groups. As noted by Rosenbaum (2002), hidden bias, and hence lack of robust estimators may still arise if there are unobserved variables that simultaneously affect assignment into treatment and the outcome variable. Rosenbaum (2002) has therefore suggested a bounding approach to address the problem of hidden bias in matching models. The goal of this approach is to determine how strongly an unmeasured variable must influence the selection process to undermine the implications of the matching process.

3. Data and Descriptive Statistics

The data used in the analysis were collected with a survey of 325 farmers in seven cotton-producing districts in the Punjab province. The Punjab province was chosen for the survey because almost 80% of the cotton production in the country takes place there[13]. A stratified random sampling technique was employed to select the farmers in the districts of Bahawalpur, Bahawalnagar, Vehari, Khanewal, Multan, Lodhran and Rahim Yar Khan. The sample ensured representation of adopters and non-adopters of Bt cotton, major landholdings and farm household types. The survey was conducted through questionnaire interviews by local enumerators who were trained prior to the exercise, which took place between August and December 2007. The data collected included information on input use, costs, yields and output prices, farm-level characteristics as well as socioeconomic characteristics of the households.

Table 1 presents definitions and descriptive statistics for the variables used in the empirical analysis. The survey showed that about 62% of households adopted the new technology. The average age of farmers was almost 42 years, whereas the mean number of years of schooling was about nine years. The mean land owned by the household was 31 acres. The cotton area cultivated per household was about 32

[13] About 99% of cotton production in Pakistan takes place in the Punjab and Sindh provinces. Farming structures for cotton production are similar in Punjab and Sindh provinces. Environmental and climatic conditions, particularly water constraints, in the other provinces are not suitable for cotton production.

acres, showing that some land was rented for cotton production. Average household income was Rs 46,415, with 8.3% of the household falling below the purchasing power parity poverty line. The purchasing power parity poverty line used in the calculations is the US$ 1.08 per day per person suggested by the World Bank for Pakistan. Average yields were found to be 904 kg per hectare, showing a yield difference of about 20% to non-Bt cotton. It needs to be mentioned that these yields are much lower than the yields reported for India and China. Specifically, Crost et al. (2007) reported yields of about 2,065 kg/ha for India, whereas Huang et al. (2002 a, b) showed yields that averaged about 3,481 kg/ha for China. However, the yield levels for Pakistan appear to be much higher than those reported by Shankar and Thirtle (2005) for South Africa, where yields were around 498 kg per hectare.

Table 1: Definition of variables and descriptive statistics

Variable	Description	Sample Mean	Standard deviation
Dependent variable			
Bt Cotton	1 if farmer plants Bt varieties, 0 otherwise	0.62	0.49
Cotton yields	Cotton output in kg/ha	905	0.2
Household income	Total household income (Rupees)	46,415	3,073
Net returns	Net returns per acre from cotton production in Rupees	7,840	826
Pesticide	Pesticide sprayed in litres during cotton season	3.79	0.08
Poverty	Head count index is used to estimate household poverty	0.08	0.02
Independent Variables			
Age	Age of the cotton farmer in number of years	42	12.4
Education	Number of years of schooling of cotton farmer	9.0	4.3
Household head	1 if farmer is head of household, 0 otherwise	0.62	0.02
Household size	Number of people residing in household	9.5	5.4
Land owned	Number of acres owned by the farmer	31.3	56.2
Cotton area	Number of acres planted under cotton crop	31.8	49.7
Soil fertility	1 if soil is fertile, 0 otherwise	0.44	0.03
Tractor	1 if farmer owns a tractor, 0 otherwise	0.64	0.47
Tube well	1 if farmer owns a tube well, 0 otherwise	0.66	0.03
TV	1 if farmer owns a TV, 0 otherwise	0.75	0.02
Vehicle	1 if farmer owns a vehicle, 0 otherwise	0.2	0.02
Membership	1 if farmer holds any organization membership, 0 otherwise	0.2	0.4
Extension contact	1 if farmer has contact with extension agent, 0 otherwise	0.81	0.4
Credit	1 if farmer has access to credit facility, 0 otherwise	0.34	0.02
Labour availability	1 if labour is available during cotton season, 0 otherwise	0.83	0.37
Agri. Income source	1 if agriculture is the main income source, 0 otherwise	0.80	0.02
Non-farm work	1 if farmer is involved in non farm work, 0 otherwise	0.20	0.40
Locations and district dummies			
Bahawalpur	1 if the farmer is located in Bahawalpur district, 0 otherwise	0.17	0.37
Bahawalnagar	1 if the farmer is located in Bahawalnagar district,0 otherwise	0.09	0.29
Khanewal	1 if the farmer is located in Khanewal district, 0 otherwise	0.13	0.34
Vehari	1 if the farmer is located in Vehari district, 0 otherwise	0.16	0.36
Multan	1 if the farmer is located in Multan district, 0 otherwise	0.06	0.24
Lodhran	1 if the farmer is located in Lodhran district, 0 otherwise	0.18	0.39
Rahim Yar Khan	1 if the farmer is located in Rahim Y. K. district, 0 otherwise	0.19	0.39

Source: Survey data

Table 2 presents differences in the characteristics of adopters and non-adopters, with their t-values. The t-value suggests that there are some differences between adopters and non-adopters with respect to farm-level and household characteristics. In particular, there appears to be differences in land ownership, ownership of tractors, tube well and vehicles, as well as membership in organizations. Thus, adopters generally own more land than non-adopters. There are also significant differences in cotton yields, household income and the poverty status. Quite interesting is the statistically significant difference in the application of pesticides between adopters and non-adopters. Although, Bt cotton provides resistance to the tobacco budworm (Heliothis virescens) and cotton bollworm (Helicoverpa gelotopoeon), there are other cotton pests in Pakistan to which the new technology does not provide resistance. Hence, farmers cultivating Bt cotton still need to apply some pesticides to their fields. The lower levels of application by adopters indicate that some level of success for the new technology has been achieved. There appear to be no significant difference in the quality of soils between adopters and non-adopters.

The land-size categories of adopters and non-adopters are also presented in table 3. The differences suggest an apparently stable correlation between the incidence of adoption and land-asset ownership, indicating that most adopters are large-scale farmers followed by medium and small scale farmers respectively.

Table 2: Differences in characteristics of adopters and non-adopters (sample mean)

Characteristic	Adopters	Non-adopters	Difference	t-values
Age (years)	42.4	41.31	1.1	0.7
Education (years)	9.2	8.5	0.7	1.0
Household head (dummy)	0.64	0.57	0.1	1.3
Adult males (number)	2.0	2.1	-0.1	-0.7
Total family (number)	9.1	10.1	-1.0*	-1.7
Land owned (acres)	36	23.4	12.6**	2.0
Cotton area (acres)	32	22.1	9.6**	2.0
Soil fertility (dummy)	0.5	0.4	0.1	1.4
Cotton yields (kg/acre)	368	296	72***	2.9
Tractor (dummy)	0.72	0.516	0.21***	3.8
Tube well (dummy)	0.74	0.54	0.20***	3.6
TV (dummy)	0.76	0.66	0.1*	1.8
Vehicle (dummy)	0.2	0.13	0.1***	2.9
Membership (dummy)	0.1	0.2	-0.1*	-1.7
Extension contact (dummy)	0.8	0.66	0.1***	3.2
Labour availability (dummy)	0.8	0.77	0.01**	2.2
Agri. income source (dummy)	0.8	0.77	0.01	0.7
Non-farm work (dummy)	0.2	0.21	-0.01	-0.3
Household income (Rupees)	54,960	32,527	22,433***	3.6
Net returns (Rupees/acre)	8,627	6,484	2,142	1.2
Pesticide spray (liters/acre)	3.5	4.12	-0.6***	-4.0
Poverty	0.02	0.2	-0.1***	-3.1
Credit	0.3	0.3	-0.0	-0.0
Number of Farmers	201	124		

Note: Significance of t-statistics of mean difference is at the *10%, **5% and ***1% level.

Table 3: Distribution of sample households by land holding

Category	Land owned (Acres)	Adopters Frequency (Number of Farmers)	Percentage	Non adopters Frequency (Number of Farmers)	Percentage	Overall Frequency (Number of Farmers)	Percentage
Landless	0 acres	18	8.95	9	7.25	27	8.31
Small	>0-5acres	22	10.94	31	25.0	53	16.30
Medium	>5-12.5 acres	49	24.37	43	34.67	92	28.30
Large	>12.5 acres	112	55.55	41	33.10	153	47.07
Total		201		124		325	

The incidence of poverty and technology adoption is presented in table 4. The incidence of poverty, as well as depth and severity of poverty all appear to be lower among the adopters of Bt cotton. The headcount index is the percentage of the population living in households with income per capita below the poverty line. However, the headcount index ignores the amount by which the expenditures of the poor fall short of the poverty line. Hence, the poverty gap index which gives the mean distance below the poverty line as a proportion of the poverty line is also computed. The squared poverty gap index which indicates the severity of poverty is computed by weighting the individual poverty gaps by the gaps themselves, so as to reflect inequality amongst the poor. In terms of farm categories, the incidence of poverty revealed that about 19% of small farmers, 9% of medium farmers and 3% of large farmers were below the poverty line.

Table 4: Poverty indicators among adopters and non-adopters of Bt cotton

Indicator	Adopters	Non- adopters	Overall
Head count index	0.024	0.177	0.083
Poverty gap	0.015	0.122	0.055
Severity of poverty	0.009	0.082	0.037

Note: For the above calculations purchasing power parity (PPP) US$ 1.08 per person per day is used as poverty line.

Although the comparisons in table 2 do reveal some significant differences between adopters and non-adopters, mean differences do not account for the effect of other characteristics of farmers and cannot be taken as evidence for the specific effects of adoption. Caliendo and Kopeinig (2008) point out that to obtain the unconfounded effect of adoption on outcomes, only variables that influence both adoption and outcomes and are not affected by adoption should be used in the propensity score models when matching is performed[14]. Smith and Todd (2005) also argue that the choice of variables should be guided by economic theory, sound knowledge of previous research and the institutional setting within which treatment and outcomes are measured. The variables employed in this study are based on previous research on determinants of adoption of new varieties (Abdulai and Huffman, 2005; Diagne and Demont, 2007).

[14] Wooldridge (2005) illustrates that including controls that are themselves affected by treatment generally violates the unconfoundedness assumption.

4. Empirical Results

The empirical analysis was conducted using the STATA statistical package. As indicated earlier, the matching process is preceded by specification of the propensity scores for the treatment variable. A logit model was employed to predict the probability of adopting the Bt cotton variety. The effect of adoption of Bt cotton on input demand, yields, household income and poverty was estimated with NNM and KBM. The results of the logit specification of the propensity score are reported in table 5.

A glance at table 5 indicates that a number of the household and farm-level variables do influence the likelihood of adopting Bt cotton. In particular, education, access to credit and visits by extension officers tend to facilitate adoption of Bt cotton. The common support condition is imposed in the estimation by matching in the region of common support.

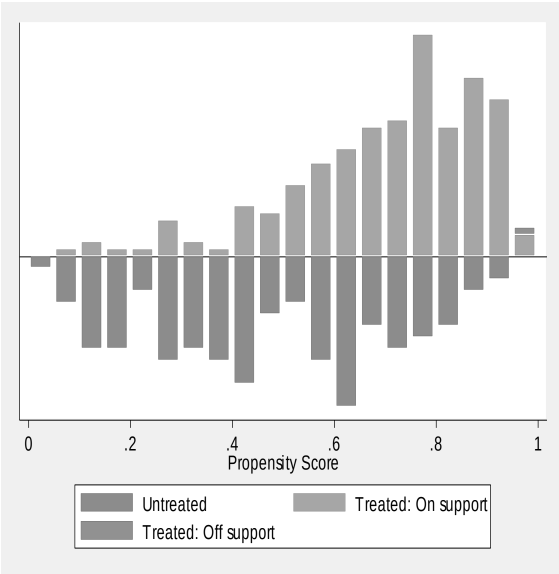
Table 5: Propensity score for Bt cotton adoption (logit estimates)

Variable	Coefficient	Standard error	z
Age (years)	-0.0	0.0	-0.57
Education (years)	0.1	0.0	0.24
Household head (dummy)	0.7**	0.3	2.12
Land owned (acres)	-0.0	0.0	-1.21
Soil fertility (dummy)	0.5*	0.3	1.93
Adult males (>16 years)	-0.0	0.1	-0.00
Tube well (dummy)	0.5**	0.3	1.98
Tractor (dummy)	0.7**	0.3	2.30
TV (dummy)	0.3	0.3	0.97
Vehicle (dummy)	0.5	0.4	1.40
Credit (dummy)	0.2**	0.1	2.08
Membership (dummy)	-0.4	0.4	-1.02
Extension contact (dummy)	0.7**	0.3	2.23
Labour availability (dummy)	0.0	0.4	0.00
Agriculture income source (dummy)	1.7*	0.9	1.89
Non-farm work (dummy)	1.4	0.9	1.58
Districts fixed effects (district dummies)			
Bahawalpur	-1.6***	0.4	-3.55
Bahawalnagar	0.13	0.5	0.30
Khanewal	0.5	0.5	1.17
Vehari	-0.2	0.4	-0.58
Multan	2.0***	0.7	2.63
Lodhran	0.3	0.4	0.72
Constant	-3.2***	1.1	-2.74
Number of observations	325		
Pseudo R square	0.19		

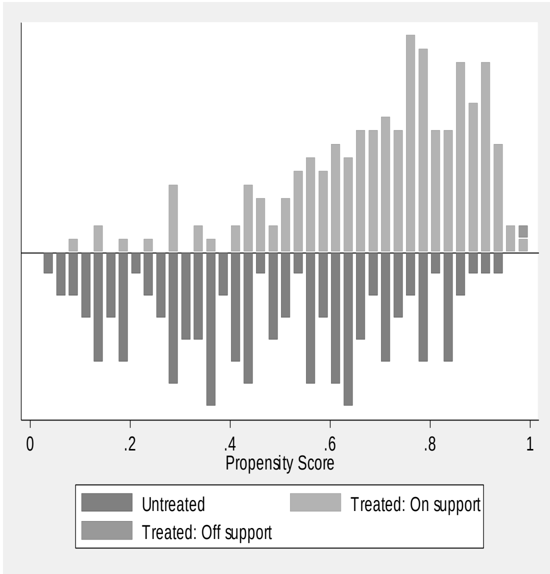
Note: Significance of z-statistics of mean difference is at the *10%, **5% and ***1% level.

Figure 1 presents the distribution of the propensity scores as well as the region of common support. The figures demonstrate the bias in the distribution of the propensity scores between the groups of adopters and non-adopters. They clearly reveal the significance of proper matching and imposition of common support condition to avoid bad matches.

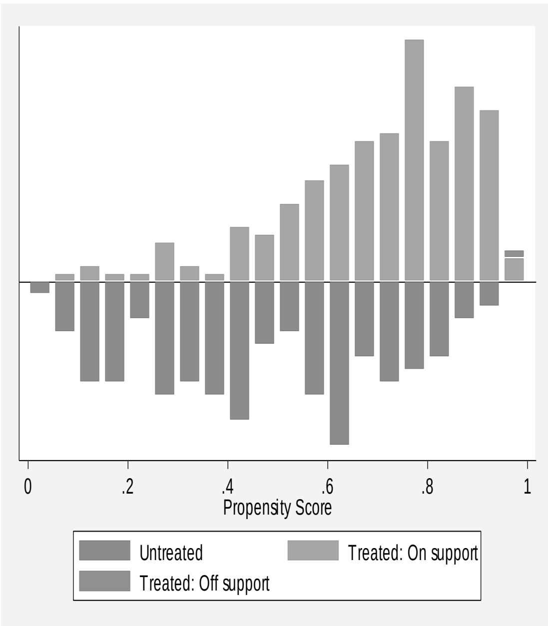
Figure 1: Propensity score distribution and common support for propensity score estimation



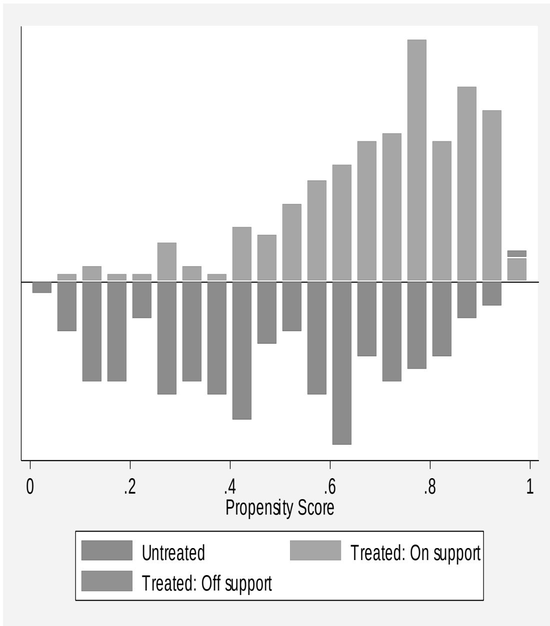
Effect on cotton productivity



Effect on household income



Effect on pesticide demand



Effect on household poverty

Note: Treated on support indicates the individuals in the adoption group who find a suitable match, whereas treated off support indicates the individuals in the adoption group who did not find a suitable match.

Tables 6 and 7 present the average treatment effects estimated by KBM and NNM methods, as well as the indicators of matching quality from the matching models. The matching results from both KBM and NNM approaches in table 6 generally indicate that adoption of Bt cotton exerts a positive and significant impact on demand for pesticides and the poverty level. Specifically, the KBM and NNM causal effects of adoption on productivity (measured in kg, at 50 and 62 kg, respectively) suggest that yields of Bt cotton growers are higher by about 50-62 kg / acre than non-Bt cotton growers. On the other hand, the KBM and NNM causal effects on demand for pesticide range between -0.62 and -0.68, suggesting that the demand for pesticides is lower for adopters by 0.62-0.68 l/acres. The results here are generally in line with the findings by Qaim and Zilberman (2003) for different states of India, where trials showed that Bt cotton reduces pest damage and increases yields.

The estimates from the KBM and NNM also indicate that adoption of Bt cotton exerts a positive and statistically significant effect on household income and welfare. The KBM and NNM causal effects of adoption are about Rs 16,500 and 17,000, respectively, implying that average household incomes of adopters are between Rs 16,500 and 17,000 higher than non-adopters. The probability of adopters being poor was found to be lower by about 11-14%, relative to non-adopters.

As mentioned in the discussion earlier, the main objective of propensity score estimation is to balance the distribution of relevant variables in the groups of adopters and non-adopters rather than obtaining precise prediction of selection into treatment. The reduction in the median absolute standardized bias between the matched and unmatched models is employed to examine the balancing powers of the estimations. As is evident in the fourth and fifth column of table 7, the results reveal that substantial reduction in bias was obtained through matching. The pseudo-R^2 from the propensity score estimation and from re-estimation of the propensity score after matching are also presented in the sixth and seventh columns of table 7. The *p*-values of the likelihood ratio tests before and after matching are also presented in the eighth and ninth columns of the table. The joint significance of the regressors is always rejected after matching, whereas it was never rejected at any significance level before matching, suggesting that there is no systematic difference in the distribution of covariates between adopters and non-adopters after matching.

Results from the sensitivity analysis for the presence of hidden bias are also presented in the fourth column of table 6. Given that sensitivity analysis for insignificant effects is not meaningful, Rosenbaum bounds were calculated only for treatment effects that are significantly different from zero (Hujer et al., 2004)[15]. Generally, the results compare favourably with findings from other studies and are insensitive to hidden bias (e.g. Faltermier and Abdulai, 2009). For example, for the impact of technology adoption on productivity, the sensitive analysis suggest that at a level of $\Gamma = 1.75$, causal inference of the significant impact of adoption would have to be viewed critically. The value implies that if individuals that have the same Z-vector differ in their odds of adoption by a factor of 75%, the significance of the participation effect on income may be questionable. The lowest critical value of Γ is 1.45-1.50, whereas the largest critical value is 2.15-2.20. We can therefore conclude that even large amounts of unobserved heterogeneity would not alter the inference about the estimated effects.

[15] The lower bound scenarios underscoring the under-estimation of the treatment effect are less interesting and therefore omitted in our analysis.

Table 6: Average treatment effects and results of sensitivity analysis

Matching algorithm	Outcome	ATT	Bandwidth/Caliper	Critical level of hidden Bias (Γ)	Number of treated	Number of control
Kernel-based matching (KBM)	Cotton yield (kg/acre)	50*** (2.75)	0.60	1.70-1.75	189	119
	Household income (Pak Rupees)	16,463.4*** (2.92)	0.60	1.45-1.50	189	119
	Pesticide (l /acre)	-0.62*** (-2.70)	0.60	1.85-1.90	189	119
	Poverty	-0.143*** (-3.71)	0.60	2.15-2.20	189	119
Nearest neighbour matching (NNM)	Cotton yield (kg/acre)	62*** (2.43)	0.01	1.60-1.65	192	103
	Household income (Pak Rupees)	17,061.7** (2.39)	0.01	1.50-1.55	192	103
	Pesticide (l /acre)	-0.68*** (-2.59)	0.05	1.95-2.00	200	123
	Poverty	-0.135** (-2.10)	0.03	2.10-2.15	178	108

Note: Number in parentheses are t-values. Values are significantly different from zero at ***1%, **5% and *10% level. ATT is the average treatment effect for the treated. In case of KBM bootstrapped statistics is 50 replications. In case of KBM bandwidth are reported, while in case of NNM caliper are reported.

Table 7: Indicators of covariate balancing, before and after matching

Matching algorithm	Outcome	Median absolute bias (before matching) %	Median absolute bias (after matching) %	(Total)% bias reduction	Pseudo R^2 (unmatched)	Pseudo R^2 (matched)	*p*-value of LR (unmatched)	*p*- value of LR (matched)
Kernel-based matching	Cotton yield (kg/acre)	24.7	11.0	55.4	0.178	0.042	0.000	0.556
	Income (Pak Rupees)	23.2	10.3	55.7	0.169	0.003	0.000	0.984
	Pesticide (l/acre)	23.1	4.32	81.3	0.184	0.025	0.000	0.943
	Poverty	22.9	12.7	45.3	0.171	0.021	0.000	0.964
Nearest neighbor matching	Cotton yield (kg/acre)	14.1	8.6	39.0	0.240	0.053	0.000	0.401
	Income (Pak Rupees)	13.5	6.3	46.7	0.243	0.055	0.000	0.683
	Pesticide (l/acre)	14.5	5.9	59.3	0.244	0.048	0.000	0.727
	Poverty	12.8	4.5	64.0	0.241	0.056	0.000	0.390

Table 8 presents results for the causal impacts of adoption of Bt cotton on productivity, household income and poverty status for different categories of land ownership. The results generally reveal that even within the different farm size groups, adoption tends to positively and significantly affect productivity, with the impact declining with increasing land ownership. The income effect of technology is the highest among the large farms, consistent with the earlier observation of positive relationship between land ownership and household income. A similar observation is reported by Mendola (2007) for Bangladesh. It is also significant to note that the adoption of Bt cotton exerts a negative and statistically significant impact on poverty among the small-scale farmers, but negative and insignificant effects on the medium and large farmers, despite the income effect being the greatest for the larger farmers. This finding suggests that targeting small-scale farmers with new agricultural technology can have welfare implications by helping such farmers out of poverty. The indicators of covariates balancing are presented in table 9.

Table 8: Average treatment effects and results of sensitivity analysis according to farming category

Farming category	Matching algorithm	Outcome	Caliper	ATT	Critical level of hidden bias (Γ)	Number of treated	Number of control
Small (0-5 acres)	Nearest neighbor matching	Cotton yield (kg /acre)	1.0	99* (1.70)	2.05-2.10	41	39
		Household income (Pak Rupees)	0.5	20184.1*** (4.33)	1.20-1.25	41	39
		Pesticide (l/acre)	0.01	-0.608* (-1.69)	1.60-1.65	41	39
		Poverty	0.02	-0.445** (-2.95)	2.05-2.10	41	39
Medium (>5-12.5 acres)	Nearest neighbor matching	Cotton yield (kg /acre)	0.05	89.2* (1.89)	1.95-2.0	49	43
		Household income (Pak Rupees)	0.1	19506.8*** (2.64)	1.95-2.00	49	43
		Pesticide (l/acre)	0.02	-1.83** (-2.15)	1.45-1.50	49	43
		Poverty	1.0	-0.083 (-0.78)	----	49	43
Large (>12.5 acres)	Nearest neighbor matching	Cotton yield (kg/acre)	0.05	80* (1.72)	1.50-1.55	40	30
		Household income (Pak Rupees)	0.06	27860.2* (1.82)	1.65-1.70	100	44
		Pesticide (l/acre)	0.05	-0.55 (-1.33)	----	40	30
		Poverty	0.01	-0.108 (-1.40)	----	100	44

Note: Numbers in parentheses are *t*-values. Values are significantly different from zero at ***1%, **5% and *10% level. ATT is the average treatment effect for the treated.

Table 9: Indicators of covariate balancing, before and after matching

Farming Category	Outcome	Caliper	Median absolute bias (before matching) %	Median absolute bias (after matching) %	(Total)% bias reduction	Pseudo R^2 (unmatched)	Pseudo R^2 (matched)	*p*-value of LR (unmatched)	*p*-value of LR (matched)
Small	Cotton yield (kg/acre)	1.0	32.48	13.47	58.52	0.565	0.043	0.000	0.986
	Income (Pak Rupees)	0.5	27.58	14.73	46.59	0.330	0.029	0.000	0.900
	Pesticide (l/acre)	0.01	27.44	13.51	50.76	0.332	0.060	0.000	0.383
	Poverty	0.02	27.58	19.25	25.88	0.330	0.112	0.000	0.922
Medium	Cotton yield (kg/acre)	0.05	27.14	16.98	37.43	0.391	0.030	0.000	0.460
	Income (Rupees)	0.1	25.88	17.91	30.80	0.392	0.023	0.000	0.730
	Pesticide (l/acre)	0.02	25.23	15.89	37.02	0.390	0.027	0.000	0.211
	Poverty	1.0	25.40	18.28	71.96	0.392	0.033	0.000	0.554
Large	Cotton yield (kg/acre)	0.05	22.44	14.35	36.05	0.244	0.022	0.000	0.155
	Income (Pak Rupees)	0.06	22.50	13.03	42.10	0.264	0.187	0.000	0.477
	Pesticide (l/acre)	0.05	22.75	7.86	65.45	0.265	0.129	0.000	0.329
	Poverty	0.01	20.09	8.03	39.97	0.160	0.013	0.000	0.436

Note: Nearest neighbour matching (2) results.

5. Conclusions

The direct effects of new agricultural technology on poverty reduction are the productivity benefits enjoyed by the farmers who actually adopt the technology. These benefits usually manifest themselves in the form of higher farm incomes. This study employed a propensity score-matching approach to examine the direct effects of adoption of *Bacillus thuringiensis* (Bt) cotton on yields, pesticide demand, household income and poverty reduction, using cross-sectional data from a survey of farmers in the Punjab province of Pakistan. The analysis explicitly considers the causal relationship between adoption of the new technology and household welfare, thus addressing counterfactual questions that may be significant in predicting the impacts of policy changes.

The empirical results from the analysis show that adoption of the new technology had positive and significant effects on cotton yields, household income and poverty reduction, and negative impact on the use of pesticides. For example, the estimates reveal that cotton yields are by 50 kg/acre higher for farmers who adopt Bt cotton. This can be considered as the opportunity cost of not adopting the new technology. The positive and significant impact of the technology on yields and household incomes reaffirms the potential role of new agricultural technology in directly reducing rural poverty through increased farm household incomes. The negative and significant impact of the technology on the demand for pesticide shows that as an inbuilt pest resistance mechanism. Bt cotton could result in substantial ecological benefits. The reduced demand for pesticides is encouraging, not only for ecological reasons, but also for health reasons, as they are potentially harmful for human health, particularly under the conditions of use in several developing countries.

The estimates differentiated by land ownership indicate that the productivity gains from Bt cotton are higher for small farmers compared to medium and large farmers. The income effect of technology appears to be higher for large farmers. However, adoption tends to help small scale farmers out of poverty but exert no statistically significant impacts on medium and large farmers' poverty status. The policy implications of this finding is that targeting the small-scale farmers with the new agricultural technology can help improve their farm productivity, income and reduce poverty among these households. Promising policies in this direction include increasing their access to information to reduce uncertainty about new technologies and formal credit for them to overcome liquidity constraints. In addition, efforts to improve their human capital in the form of education and providing them with better infrastructures, as well as advanced extension services, would go long way to help facilitate the adoption of new technologies.

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Chapter 4

Impact of Land Tenure on Investment and Efficiency: Evidence from Pakistan

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Chapter 4

Impact of Land Tenure on Investment and Efficiency: Evidence from Pakistan

Abstract

While recent studies appear to show a positive impact of secured land rights on land-related investments, the relationship between land rights and farm efficiency remains unclear. In this paper, we explore the relationship between land rights and farmers' decisions to invest in land improvement measures, as well as its potential impacts on farm efficiency from a theoretical and empirical perspective. In the empirical analysis we use household data from the Punjab province in Pakistan. A two-stage tobit specification is employed to analyse the land-tenure investment relationship, while a stochastic profit frontier model is used to examine the impact of tenure security on farm efficiency. The empirical results generally show that land tenure security enhances investments in land-improving measures. Owner-cultivators were found to be more efficient than sharecroppers and fixed-renters, underlying the significance of tenure security in enhancing efficient allocation of resources in rural households.

Key words: Land tenure arrangements, Investment, Soil capital, Efficiency, Pakistan.

1. Introduction

The widespread support for reforming land rights in developing countries rests on the premise that farmlands held under secured land rights are more productive than farmlands held under other forms of agreements (Laffont and Matoussi, 1995; Banerjee et al., 2002). Tenure security encourages the farmer to undertake soil improving and productivity-enhancing investments, since it provides him with the confidence that he will remain on the land long enough to enjoy the benefits of his investment. On the other hand, insecure property rights in land create a disincentive to invest, since the uncertainty of the user's claim to land lessens expected future returns to investments (Jacoby and Mansuri, 2008). The consequence of declines in demand for investment is lower productivity. Land reforms that confer secured rights on farmlands should therefore enhance production efficiency of such lands (Gavain and Fafchamps, 1996).

The relevance of land tenure arrangements for investment and efficient allocation of resources among rural farm households in developing countries has resulted in significant interest in this area of research over the last three decades (e.g., Feder and Onchan, 1987; Banerjee et al., 2002; Jacoby et al., 2002; Deiniger and Jin, 2006; Jacoby and Mansuri, 2009). Although the empirical literature on this issue, particularly on Sub-Saharan Africa, is somehow inconclusive, the recent studies suggest that tenure security enhances investment in soil quality. For example, Deininger and Ali (2008) show that full land ownership, compared to mere land-use rights exerts a statistically significant and economically large effect on investment and productivity of land use in Uganda.

Despite the large empirical literature, very little evidence exists on the effect of alternative tenure arrangements on efficiency. Banerjee et al. (2002) find empirical support for the hypothesis that secured tenure rights positively affected agricultural productivity in West Bengal. On the other hand, Jacoby et al. (2002) conclude from their study on rural China that guaranteeing land tenure in the north-eastern part of China would yield only minimal efficiency gains. In their recent study on Pakistan, Jacoby and Mansuri (2008) report a positive relationship between tenure security and investment. However, they could not investigate the impact of tenure security on efficiency due to data limitations, and therefore suggest that this issue should be considered as an important future research area. As argued by Gavian and Ehui (1999), from a policy view point, better information on the relative efficiency of farm lands under different tenure arrangements would provide a sound indication of the extent to which land tenure systems affect resource use and as such overall productivity of farming operations.

In this paper, we provide some evidence on the relationship between tenure security and productivity enhancing investments as well as how tenure security impacts on farm efficiency in rural Pakistan. In the theoretical part of the study we employ an inter-temporal framework to examine the link between different land tenure arrangements and investments as well as how these arrangements affect farm productivity. Moreover, this setting allows us to formulate the mutual interdependence of investment and land tenure arrangements in the form of a two-stage optimal control. The empirical work, which employs a sample of 325 cotton farmers from Punjab province in Pakistan, begins by analyzing the effects of different tenure regimes on investments in organic and mineral fertiliser, and the cultivation of leguminous crops (green manure).

Tenure security is measured by land ownership compared with arrangements like fixed-rent and sharecropping contracts. We use an empirical specification that accounts for potential endogeneity for tenure regimes that might occur, if farmers engage in productivity enhancing investments to increase security of property rights. The results clearly indicate that tenure security enhances investments in land improving measures. The second part of the analysis uses a stochastic profit frontier to investigate whether tenure insecurity discourages an efficient use of resources. Results suggest that owner-cultivators are more efficient than fixed-renters and sharecroppers, confirming the importance of tenure security in promoting farm efficiency in developing countries.

1.2 Land Tenure and Land Reforms in Pakistan

As in other parts of the developing world, access to land, as well as the security of land tenure contracts determine to a large extent the social status and economic well-being of the members of the rural society in Pakistan (Haider and Kuhnen, 1974). After independence in 1947, the distribution of land ownership was highly skewed, with less than 1% of the farmers holding more than 25% of the total agricultural land. At the other extreme, about 65% of the farmers held some 15% of the farmland in holdings of about two hectares or less. The unequal distribution of land contributed to tenancy arrangements such as sharecropping and fixed-rent contracts. Evidence shows that more than 50% of the total farm land is cultivated by tenants or sharecroppers (Pakistan Agriculture, 1995).

The unequal distribution of land in the country resulted in two main land reform attempts. The first attempt was in 1959, when land reforms fixed the ceiling for private ownership of land at 500 acres for irrigated and 1,000 acres for non-irrigated land. A major problem of this reform was that ceilings were fixed in terms of individuals rather than families such that families could still own a large number of acres of land. A second attempt was therefore made in 1972, in which the ownership ceiling was reduced to 150 acres of irrigated and 300 acres of non-irrigated land. Although the reforms appeared good on paper, the implementation was quite poor. Less than 0.9 million acres of land were acquired for redistribution, which was about one-third of the land resumed under the 1959 land reforms. Moreover, the ceilings remained in terms of individuals rather than families. Hence, a number of large landowners still managed to keep their holdings within an extended joint family framework, while giving away only marginal and less productive lands (Pakistan Agriculture, 2009). Land ownership in the country therefore remains highly concentrated.

As indicated above, the major forms of land tenure arrangements in the country and particularly in the study area are owner-operated, fixed-rent and sharecropping contracts. The owner-operated involves farmers owning and cultivating their own plots. Farmers cultivating these plots have transfer rights, including rights to sell the plots. The fixed-rent contracts involves land owners renting out land to tenants and the sharecropping contract, is an arrangement made between the landlord and the operator such that part of the output is given to the landlord as compensation for using the land. Although the sharecropping contract compared to a fixed-rent increases the risk for the landowner, it enables the landlord to align the interest of the farmer with his interests (Basu, 1992). In some cases the tenants gets one-fourth, one-sixth, or even one-eighth of output, depending on the terms of agreement and contribution made in inputs. Fixed-rent contracts are normally informal and tend to vary between one and three years, although they can extend for several years, depending upon the mutual understanding between the owner and tenant.

1.3 Conceptual Model of Land Tenure Rights and Investment

In the theoretical part of our study we initially analyse the link between tenure security and productivity enhancing investments. For this purpose, we formulate the farmer's decision problem within a dynamic framework. The solution of this problem enables us to explain the investment behaviour resulting from different land tenure arrangement and to determine the efficient investment behaviour for each tenure arrangement. We also extend the dynamic framework to a two stage optimal control approach to address potential endogeniety of land tenure that may arise.

Specifically, we model soil capital as a renewable resource and analyse its interdependence with cotton production. It is assumed here that farmers combine investments in organic fertilizers (manure), $M(t)$, cultivation of leguminous crops[16], $L(t)$, and mineral fertilizers, $F(t)$, such as NPK. Leguminous crops are cultivated in between the cotton growing periods. The variable *t* indicates calendar time. Farmers

[16] Leguminous crops are known for their ability to fix atmospheric nitrogen, because of a symbiotic relationship with certain bacteria known as rhizobia found in root nodules of these crops. This ability to form symbiosis reduces fertilizer costs for farmers, and allows legumes to be used to replenish soil that has been depleted of nitrogen.

are fixed-rent tenant, sharecropper or owner-cultivators of the land. We assume that the fixed-rent or sharecropping contract last *k* years. The parameter *k* can be interpreted as the commitment period of the landlord. As mentioned above *k* varies normally from 1 to 3 in the case of Pakistan. We define the cotton production function per hectare by $Y(S(t), M(t), L(t), F(t))$, where $S(t)$ represents soil capital and the remaining variables are as defined above. Following the standard convention we assume that the function $Y(\cdot)$ is strictly concave in its arguments. Moreover, since manure, the cultivation of leguminous crops and mineral fertilizers are close substitutes in the short run, we assume that $Y(\cdot)$ is additive separable in *M(t)*, *L(t)*, and *F(t)*. Consequently, the cross deviations with respect to these variables is zero. Yet, the application of manure or the cultivation of leguminous crops has a positive impact on the evolution of soil capital in the medium-term perspective, and leads to an increase in soil productivity. However, an increase in $S(t)$ decreases the marginal productivity of *M(t)*, *L(t)*, and *F(t)*. Therefore, we assume that the cross derivatives Y_{SM}, Y_{SL} and Y_{SF} are negative. On the other hand, a decrease in $S(t)$ results in the three cross derivatives being positive.

Our focus is on investments in soil quality on a given piece of farmland[17]. Thus, the application of manure, the cultivation of leguminous crops, and the application of mineral fertilizer are assumed to affect soil capital by the factors α_M, α_L and α_F respectively, with α_M, α_L, α_F >0. Hence, the evolution of the soil quality over time is described by

$$\dot{S} = \alpha_M M(t) + \alpha_L L(t) - \alpha_F F(t) - \alpha_Y Y(S(t), M(t), L(t), F(t)),$$

where a dot over a variable denotes the operator d/dt and α_Y the decrease in soil quality in proportion to the output as a result of the extraction of nutrients with the harvest. Thus, while manure and leguminous crops have positive effects on soil quality, mineral fertilizer tends to decrease it over time.

Since current investment decisions affect the evolution of soil capital over time, we analyse the farmer's decision problem within a dynamic context. We consider the fact that the planning horizon of the farmer depends on the land tenure arrangements. In

[17] The terms soil capital and soil quality are used synonymously.

the case of fixed-rent farmers or sharecroppers, user rights of the land are transferred for *k* years so that the length of their planning horizon corresponds to $(k-0)$, where *k* indicates the final and 0 the initial year of the land-use contract. In the case of owner-cultivators, we assume that the length of their planning horizon is given by $(0,T)$, where *T* indicates the end of the planning horizon of the owner. We further assume that the farmer maximises farm profits subject to agronomic and biophysical constraints. The present value of the soil capital for the owner-cultivator at the end of the planning horizon is given by $W^0(S(T))e^{-\varphi T}$, and by $W^C(S(t+1))e^{-\varphi(k)}$ for the fixed-rent tenant or sharecropper (land-use contract). If the existing land-use contract is not renewed at time *k* the function $W^C(\cdot)$ is zero. However, if the existing land-use contract is renewed, the present value of the soil capital is a function of the farm profits in the subsequent period of the land-use contract.

The planning horizon of the subsequent land-use contract is given by $2k-k$, or in more general terms for the *i*-th number (renewal) of the land-use contract by $(ik)-(i-1)k$, *i* =1, 2,...*T/k*. We assume that the landlord communicates the extension or termination of the land-use contract with *k*-year notice, i.e., at time $(i-1)k$. To facilitate the comparison between the different tenure arrangements we postulate that the maximum number of the land-use contract is given by *T/k*. We also assume that in the case the contract is renewed, the farmer maintains the soil quality at the end of the planning horizon i*k* above the level S_{ik}, i.e., $S(ik) \geq S_{ik}$, so that the expected farm profits can be realised in the subsequent period. To simplify notation, we suppress the argument *t* of the control and stock variables unless it is required for an unambiguous notation. Given these assumptions, the fixed rent tenant's or sharecropper's decision problem for the *i*-th period, *i*= 1, 2,……..*T/k* can be stated as

$$\max_{M,L,F} J^C(t_{(i-1)k}, t_{ik}, S_{(i-1)k}, \overline{\zeta}) \equiv \int_{(i-1)k}^{ik} e^{-\varphi T}[pY(S,M,L,F) - p_M M - p_L L - p_F F - (1-\theta)p_R$$

$$-\theta\gamma pY(S,M,L,F)]dt + W^C(S(ik))e^{-\varphi(ik)} \qquad (1)$$

subject to

$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y$, with $S((i-1)k) = S_{(i-1)k}$, and $M(t), L(t), F(t) \geq 0$

The parameter γ represents the share of the yields that accrues to the landlord in the case of sharecropping[18]. In this situation θ takes the value of 1 and the cost of land is given by $\gamma \; pY(\cdot)$. In case of a fixed rent tenant $\theta = 0$, and the cost of the land is given by the constant p_R which denotes the annual land rent.

All parameters, except *i, k* and $S_{(i-1)k}$ are grouped in a vector named $\overline{\zeta}$. The components of this vector are given by *p* = price of cotton, $p_M =$price of manure, $p_L =$ "price" of cultivating a leguminous crop, $p_F =$price of mineral fertiliser, $\varphi =$discount rate, and the previously introduced parameters $\alpha_M, \alpha_L, \alpha_F, \alpha_Y, \gamma$ and p_R.

The current value Hamiltonian $H^1(t)$ associated with problem (1) yields

$$H^C(t) = pY - p_M M - p_L L - p_F F - (1-\theta) p_R - \theta \gamma p Y + \lambda^C (\alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y),$$

and the first order conditions for an interior solution are given by

$$H_M^C = pY_M - p_M - \theta\gamma pY_M + \lambda^C (\alpha_M - \alpha_Y Y_M) = 0 \tag{2}$$

$$H_L^C = pY_L - p_L - \theta\gamma pY_L + \lambda^C (\alpha_L - \alpha_Y Y_L) = 0 \tag{3}$$

$$H_F^C = pY_F - p_F - \theta\gamma pY_F + \lambda^C (\alpha_F - \alpha_Y Y_F) = 0 \tag{4}$$

$$\dot{\lambda}^C = \varphi \lambda^C - pY_s + \lambda^C \alpha_Y Y_S \tag{5}$$

$$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y, \quad S((i-1)k = S_{(i-1)k} \tag{6}$$

[18] Since we focus on the issue of different tenure regimes we use expected crop yields and do not analyse their variation and the associated question of risk-sharing between the farmer and the landlord.

Finally, the transversality condition implies that $\lambda^C(ik) = dW^C(S(ik))e^{-\varphi k} / dS$

Let the solution of the problem (1) is given by

$$J^C(M^*(t), L^*(t), F^*(t); (i-1)k, ik, S((i-1)k), \overline{\zeta}) \equiv J^{C^*}((i-1)k, ik, S((i-1)k)),$$

where the superscript * indicates the evaluation of the variable along its optimal trajectory given the parameter values of $(i-1)k, ik, S((i-1)k)$ and $\overline{\zeta}$. Hence, $J^{C^*}((i-1)k, ik, S((i-1)k))$ indicates the maximized discounted farm profits aggregated over the time horizon of *k*-years given the initial soil capital of $S((i-1)k) = S_{(i-1)k}$ for the *i*-th period of the land-use contract. Note that the terminal value of the soil quality for the *i*-th period of the land contract becomes the initial soil quality for the subsequent period. In case the farmers will be offered to renew the land-use contract the expression $W^C(S(ik))e^{-\varphi(ik)}$ can be replaced by $J^{C^*}(ik, (i+1)k, S(ik)),$ since it expresses the discount farm profits aggregated over the subsequent *k*-years. The link between the land-use contracts for different periods is given by the soil quality at the end of the period and the present value of the stream of farm profits of the subsequent periods. Hence, the overall farm profits of a sequence of land-use contracts over i^* periods of k-years is given by

$$J^{C^*}(0, i^*, k, S_0, \overline{\zeta}) \equiv \sum_{i=1}^{i^*} J^{C^*}((i-1)k, ik, S_{(i-1)k}, \overline{\zeta}) + J^{C^*}(i^*k, (i^*+1)k, S_{i^*k}, \overline{\zeta})e^{-\varphi(i^*+1)k}$$

To analyse the decision problem of the owner of the land we consider the following formulation

$$J^{O^*}(.) \equiv \max_{M,L,F} J_2(0, T, S_0, \overline{\zeta}) \equiv \int_0^T e^{-\varphi T}[pY(S, M, L, F) - p_M M - p_L L - p_F F - p_C]dt$$
$$+ W^O(S(T))e^{-\varphi(T)} \qquad (7)$$

subject to

$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y$, with $S(0) = S_0$,

and $M(t), L(t), F(t) \geq 0$

where p_C denotes the annual cost of land owned. This cost comprises of the forgone interest on own capital as well as the paid interest and capital service for borrowed capital.

The current value Hamiltonian $H^O(t)$ associated with problem (7) yields

$$H^O(t) = pY - p_M M - p_L L - p_F F - p_C + \lambda^O(\alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y),$$

and the first-order conditions for an interior solution are given by

$$H_M^O = pY_M - p_M + \lambda^O(\alpha_M - \alpha_Y Y_M) = 0 \qquad (8)$$

$$H_L^O = pY_L - p_L + \lambda^O(\alpha_L - \alpha_Y Y_L) = 0 \qquad (9)$$

$$H_F^O = pY_F - p_F - \lambda^O(\alpha_F + \alpha_Y Y) = 0 \qquad (10)$$

$$\dot{\lambda}^O = \varphi\lambda^O - pY_S + \lambda^O \alpha_Y Y_S \qquad (11)$$

$$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y, \quad S(0) = S_0. \qquad (12)$$

In addition, the terminal condition requires that $\lambda^O(T) = dW^O(S(T))e^{-\varphi T} / dS.$ The first order conditions (2)-(6) for the fixed-rent tenant or sharecropper and the conditions (8)-(12) seem to differ at first glance only by the annual payment of the sharecropper for the use of the land $-\theta\gamma pY_M$. However, a closer look reveals that the planning horizon for the fixed-rent tenant or sharecropper is only *k*-years, whereas it is *T* years for the owner-cultivator.

The solution of equations (5) and (11) yields

$$\lambda^C((i-1)k+s) = e^{\int_{(i-1)k}^{(i-1)k+s} \varphi+\alpha_y Y_S dv} \int_{(i-1)k+s}^{ik} e^{\int_{(i-1)k}^{(i-1)k+s} \varphi+\alpha_Y Y_s dv} pY_s dw + \lambda^C(ik), 0 \le s \le k, 1 \le i \le T/k$$

(13)

$$\lambda^O(t) = e^{\int_0^t \varphi+\alpha_Y Y_S dv} \int_t^T e^{-\int_0^t \varphi+\alpha_Y Y_S dv} pY_S dw + \lambda^O(T), 0 \le t \le T$$

and determines the shadow value of the soil quality at time *t*. An increase in soil quality at time *t* benefits the fixed-rent farmer's or sharecropper's farm profits at the most for *k*-years whereas the owner takes advantage of the same increase until *T*. This can be seen in equation (13) from the upper limit of the integrals which do not form part of an exponent. Hence, one can conclude that the shadow price of the fixed-rent tenant or sharecropper, λ^C, is less than the shadow price of the owner cultivator, λ^O for any identical soil quality *S*. Yet, this result cannot be extended over the entire trajectories of λ^C because the trajectories of the soil qualities will only coincide by chance. If the soil quality of the owner-cultivator is better than that of the fixed-renter or sharecropper, the term Y_S will be lower for the owner-cultivator than for the fixed-rent tenant or sharecropper due to concavity of the production function. If the upper limits of the integral $(ik = T)$ were identical one might expect in this case that λ^O is lower than $\lambda^C(t)$. However, since $\lambda^O(t)$ and $\lambda^C(t)$ are basically determined by the stream of the discounted farm profits with respect to a marginal improvement of soil quality from time *t* until the end of the planning horizon, their values depend crucially on the length of the planning horizon. Since $\lambda^O(t)$ takes into account the next *T-t* years and $\lambda^C(i-1)k+s)$ considers only the next *k-s* years, it is expected that the longer time horizon of the owner guarantees that λ^C is lower than the shadow price of the owner, λ^O, for any soil quality *S* and any remaining planning horizon.

Efficiency Investment Behaviour

In this section, we analyse the effect of the land-tenure regime on the optimal choice of manure, cultivation of a leguminous crop, and mineral fertiliser. In order to determine the optimal short-run behaviour we assume that the initial soil capital $S(0) = S_0$ is identical for all three different tenure arrangements. However, soil capital is likely to evolve differently for each tenure regime and therefore we need to consider the individual changes of *S(t)* in order to determine the optimal long-run behaviour of the different types of farmers.

Since the cross derivatives of the function *Y* involving *M, L* or *F* are zero, we can analyse the first order conditions (2)-(4) for the fixed-rent tenant or sharecropper, and the first order conditions (8)-(10) for the owner-cultivator for each choice variable, independently of the values of other choice variables provided that $S(0) = S_0$. Given the relatively short time horizon of the land-use contracts, we assume that sharecroppers and fixed-rent tenants practically do not place any value on the shadow price of the soil quality. Hence, for the graphical analysis of the first-order conditions we assume that λ^C is practically zero.

Observation 1: *If increased application of manure leads to an improvement in soil quality that is more (less) than the decline in soil quality resulting from the increase in quantity harvested, then the efficient amount of manure applied by sharecroppers (fixed-rent tenants) will be lower in the short-run than that applied by fixed-renters (sharecroppers), which in turn, will be lower (larger or less) than the amount applied by owner-cultivators.*

As shown in figure 1a (continuous lines) the solution of equation (2) demonstrate that it is efficient for sharecroppers to apply less manure M^S than for the fixed rent tenants, M^T, for whom in turn it is efficient to apply less manure than owners, M^O. This result is obtained under the assumption that the term $(\alpha_M - \alpha_Y Y_M)$ is strictly positive, i.e. an additional unit of manure leads to an increase in soil capital that is larger than the decrease resulting from the increase in quantity harvested.

It is significant to mention that the theoretical analysis presented above does not allow a unique ranking based on amounts of organic manure applied by owner-cultivators, fixed-rent tenants and sharecroppers. In figure 1b, we have depicted the opposite case, i.e. $(\alpha_M - \alpha_Y Y_M)$<0, with the result that it is efficient for owners M^O to apply less manure than sharecroppers, M^S, for whom in turn it is efficient to apply less than fixed-rent tenants, M^T. Finally, it is also possible that the sign of $(\alpha_M - \alpha_Y Y_M)$ changes with the value M. In this situation the rankings obtained previously depend on the values of M, p, p_M and γ. One possible outcome is depicted in figure 2. Overall, the determination of the ranking requires the specification of the parameters. Once, these values are determined, the ranking can be obtained from the solution of the first order conditions (2) and (8).

As pointed out by Jacoby and Mansuri (2008), whether fixed-renters or sharecroppers apply less manure than owner-cultivators depends on the extent to which landlords can commit to rewarding the tenant for his investment. Where landlords fully commit to reward tenants, a fixed-rent contract essentially provides user rights for the duration of the contract and also makes it possible for tenants to claim monetary compensation for improvements in the soil quality at the end of the contract. Hence, a residual claimant, the tenant is fully incentivized and moral hazard problems consequently disappear. However, in a world of no commitment, the tenant will apply manure only to the point where the marginal profits in the current period are equal to zero and does not take into account the shadow value of the soil. This dynamic inefficiency will be common to both sharecropper and fixed-renters.

To analyse the effect of the land-tenure regime on the optimal short-run cultivated amount of leguminous crops we solve the first order conditions (3) and (9). Since the structures of these equations are identical to equations (2) and (8), the conclusions are identical. In the interest of brevity, the arguments are not repeated here. Finally, we analyse the effect of land-tenure regimes on the optimal choice of mineral fertiliser.

Observation 2: *The efficient amount of mineral fertilizer applied by owner-cultivators is in the short-run lower than the one applied by sharecroppers, which in turn is in the short-run lower than the level applied by fixed-rent tenants.*

By solving equations (4) and (10), figure 3 shows that in the short run, it is efficient for owners to apply less mineral fertiliser, F^O, than for sharecropper, F^S, for whom in turn it is efficient to apply less than fixed rent tenants, F^T. In the case of mineral fertiliser, it is possible to determine a unique ranking because the term $\alpha_F + \alpha_Y Y_F$ is strictly positive.

The previous analysis is valid for the case where $S(0) = S_0$ is identical for all three tenure arrangements. While this assumption is plausible at the beginning of the planning horizon, it is not likely to hold over a longer time horizon since owner-cultivators, sharecroppers, and fixed-rent tenants value soil capital differently. We assume that there exists a long-run equilibrium value for soil capital and this may be above or below its initial value. For this purpose, we analyse the optimal long-run investment behaviour of the different farmers for the case where $S(t) > S_0$ and where $S(t) < S_0$. In the former case, farmers have to build up soil capital over time and in the latter case it is optimal to decrease soil capital. Figures 1a and 1b show that in long-run it is optimal for the owner-cultivator to reduce the application of manure $(\overline{M}^O)$, while for sharecroppers $(\overline{M}^S)$ and fixed-rent tenants $(\overline{M}^T)$ it is optimal to increase the application of manure and mulch over time, provided that owner-cultivators build up soil capital $(S > S_0)$ and sharecroppers and fixed-rent tenants decrease soil capital $(S > S_0)$.

For the sake of brevity we do not discuss the optimal long-run investment behaviour for the case where $(\alpha_M - \alpha_Y Y_M)$ changes over time but it can be derived from figure 2 in the same way as it was done in figures 1a and 1b. Figure 3 demonstrates that it is optimal in the long-run for owner-cultivators to apply less mineral fertiliser $(\overline{F}^O)$ and for sharecroppers $(\overline{F}^S)$ and fixed-rent tenant $(\overline{F}^T)$ to apply more fertiliser over time, provided that owner-cultivators build up soil capital $(S > S_0)$ and sharecroppers and fixed-rent tenants decrease soil capital $(S > S_0)$. Although many other cases could be analysed with figures 1-3, we have focused on the most typical situations in the interest of brevity. Nevertheless, the change in the application rates of mineral and organic fertilizer of the owner-cultivator, sharecropper and fixed-rent tenant are subject to the magnitude of the shift of the graphs. Since it cannot be determined analytically, the theoretical analysis provides information about the changes in the long-run behaviour for each type of farmer but does not allow a comparison of these changes among them.

Endogeneity of Land Rights

The analysis presented above considered land rights as exogenously given. However, as indicated earlier, farmers may engage in soil-improving investments to increase the security of property rights and thus in a way reduce the probability of losing property rights in the future. To account for this potential endogeneity of land rights, we formulate the decision problem as a two stage optimal control problem. In the first stage farmers are either fixed-rent tenants or sharecroppers but may become owner-cultivators in the second stage. Thus, we examine the optimality of switching the land-tenure regime, as well as its optimal point in time. We denote this intermediate point in time by t_1, with $t_1 \in [0, k]$. The decision problem can be generally formulated as

$$\max_{M,L,F,t_1} \int_0^{t_1} pY(.) - p_M M - p_L L - p_F F - (1-\theta) p_R - \theta\gamma pY(\cdot) dt$$

$$+ \int_{t_1}^{T} pY(\cdot) - p_M M - p_L L - p_F F - p_C dt\,, \quad (14)$$

subject to

$$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y \text{, with } S(0) = S_0, 0 \le t < t_1 \le k \quad (15)$$

and

$$\dot{S} = \alpha_M M + \alpha_L L - \alpha_F F - \alpha_Y Y \text{, with } S(t_1) = S_{t_1}, t_1 < t \le T \quad (16)$$

The first order conditions according to Tomiyana (1985) are given by

$$H_M^C = H_L^C = H_F^C = 0 \text{ for } 0 < t < t_1 \le k \quad (17)$$

$$H_M^O = H_L^O = H_F^O = 0 \text{ for } t_1 < t < T \quad (18)$$

$$\dot{\lambda}^C = \varphi\lambda^C - pY_S + \lambda^C \alpha_Y Y_S \text{, for } 0 < t < t_1 \le k \quad (19)$$

$$\dot{\lambda}^O = \varphi\lambda^O - pY_S + \lambda^O \alpha_Y Y_S \text{, for } t_1 < t < T \quad (20)$$

The following continuity conditions also have to hold at the optimal intermediate point in time t_1^*.

$$H^{C^*}\Big|_{t_1^*} = \frac{\partial J^{O^*}(\cdot)}{\partial t_1}\Bigg| = H^{O^*}\Big|_{t_1^*} \tag{21}$$

$$\lambda^C(t_1^*) = \frac{\partial J^{O^*}(\cdot)}{\partial S}\Bigg|_{t_1^*} = \lambda^O(t_1^*), \tag{22}$$

where $J^{O^*}(\cdot) \equiv \max_{M,L,F} J^O(t_1, T, S_{t_1}, \overline{\zeta})$ is the value function of the second stage as defined in equation (7). The second equality sign in equation (21) and (22) follows if the function J^{O^*} is twice continuously differentiable in t_1 and S.

For $t_1^* = 0,$ the necessary conditions are given by (16), and (18) and equation (20) takes the form

$$H^{C^*}\Bigg|_{t_1^*} \le \frac{\partial J^{O^*}(\cdot)}{\partial t_1}\Bigg|_{t_1^*} \tag{23}$$

On the other hand, for $t_1^* = k$, the necessary conditions are given by (15), (17) and (19) and (21) equation takes the form

$$H^{C^*}\Big|_{t_1^*} \ge \frac{\partial J^{O^*}(\cdot)}{\partial t_1}\Bigg|_{t_1^*} \tag{24}$$

Tomiyama (1985) analysed the case where the intermediate point in time is an element of the set [*0, T*] whereas the intermediate point in our analysis is restricted to the set [0, *k*]. Hence, if the optimal intermediate point of time is not within this set, then there is the need to check the remaining sets given by $[k,2k]$,....,$[T-k,T]$. Failure of the optimal intermediate point in time to fall within any of these sets would imply non-optimality of land acquisition within the time span of *T* years. Thus, it would rather be optimal to continue cultivating the land as a fixed-rent tenant or sharecropper over the entire time span.

The optimal intermediate point in time can be determined by establishing the value function of the second stage $J_2^*(\cdot) \equiv \max_{M,L,F} J_2(t_1, S_{t_1})$. It is a function of the yet to be determined optimal intermediate point in time t_1 and the corresponding initial value of the soil quality S_{t_1}. With these provisions, the equation (14) can be reformulated to obtain.

$$\max_{M,L,F,t_1} \int_0^{t_1} pY(\cdot) - p_M M - p_L L - p_F F - (1-\theta) p_R - \theta\gamma pY(\cdot) dt + J^{O^*}(t_1, S_{t_1}) \qquad (25)$$

The solution to equation (25) is characterized by the necessary conditions defined above. For practical purposes, the analysis proceeds by finding the interior solution, $t_1^* \in (0, k)$. However, if no interior solution exists, then there is the need to check for a boundary solution, i.e. $t_1^* = 0$, and $t_1^* = k$. As mentioned above, this procedure needs to be repeated for the remaining sets of time of length, *k,* i.e. of the remaining land-use contracts. Once the optimal intermediate point of time is determined, it would be obvious whether and when it is optimal to acquire the previously cultivated land.

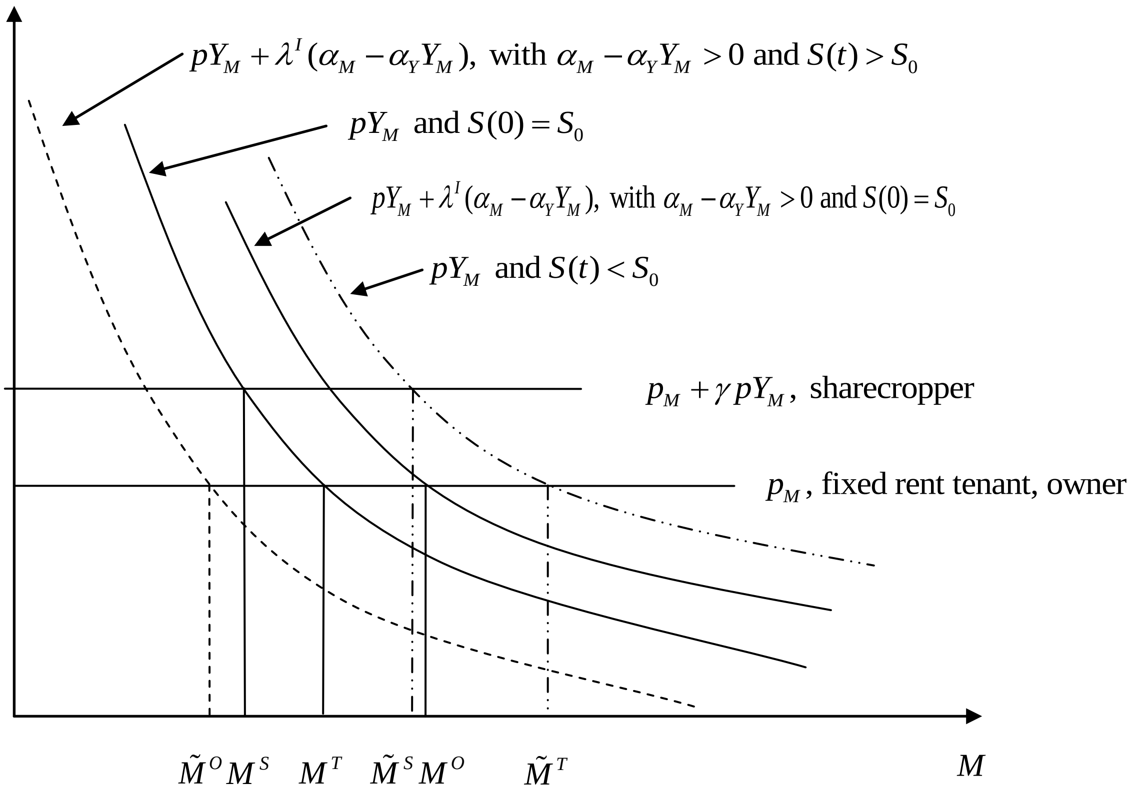

Figure 1a: The optimal amount of manure and mulch with $\alpha_M - \alpha_Y Y_M > 0$.

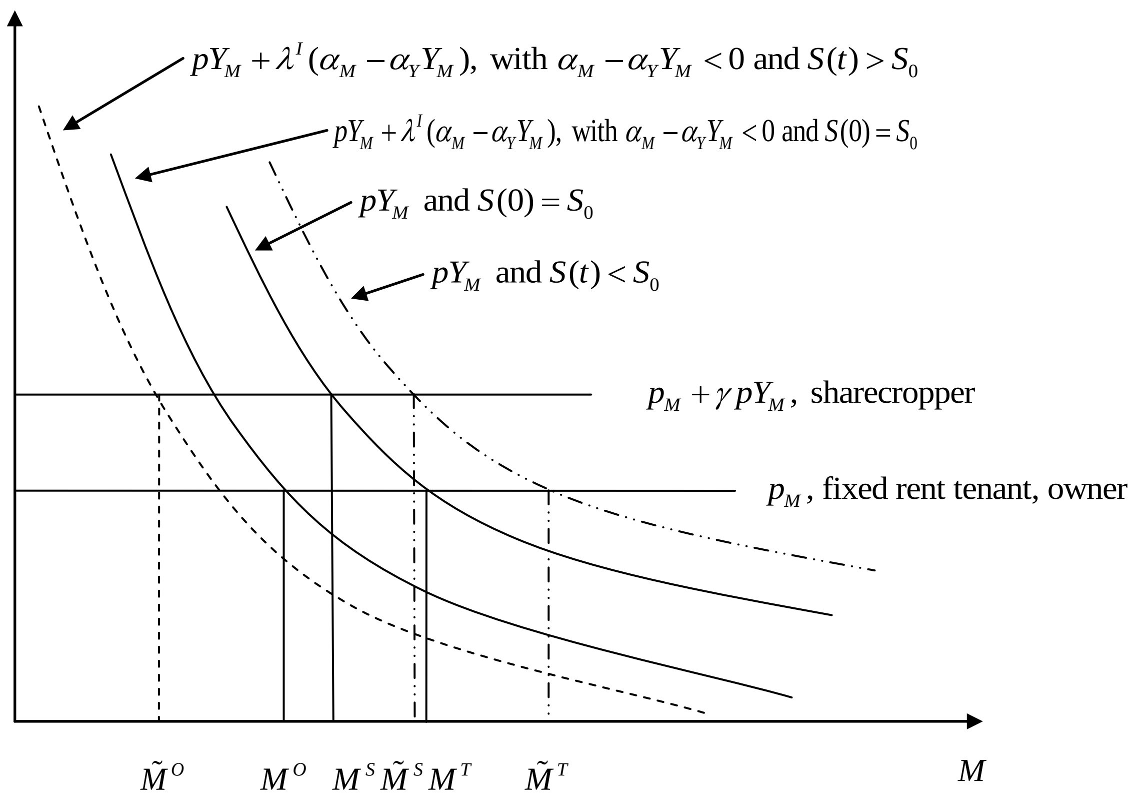

Figure 1b: The optimal amount of mulch and manure with $\alpha_M - \alpha_Y Y_M < 0$.

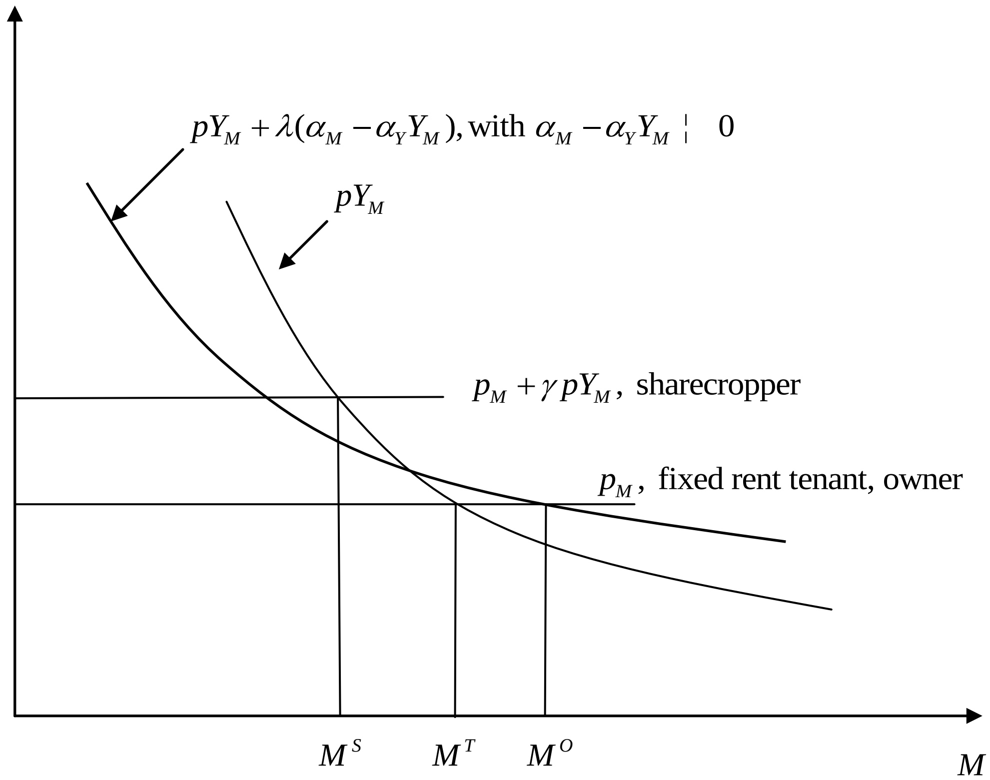

Figure 2: The optimal amount of mulch and manure with $\alpha_M - \alpha_Y Y_M$ ¦ 0.

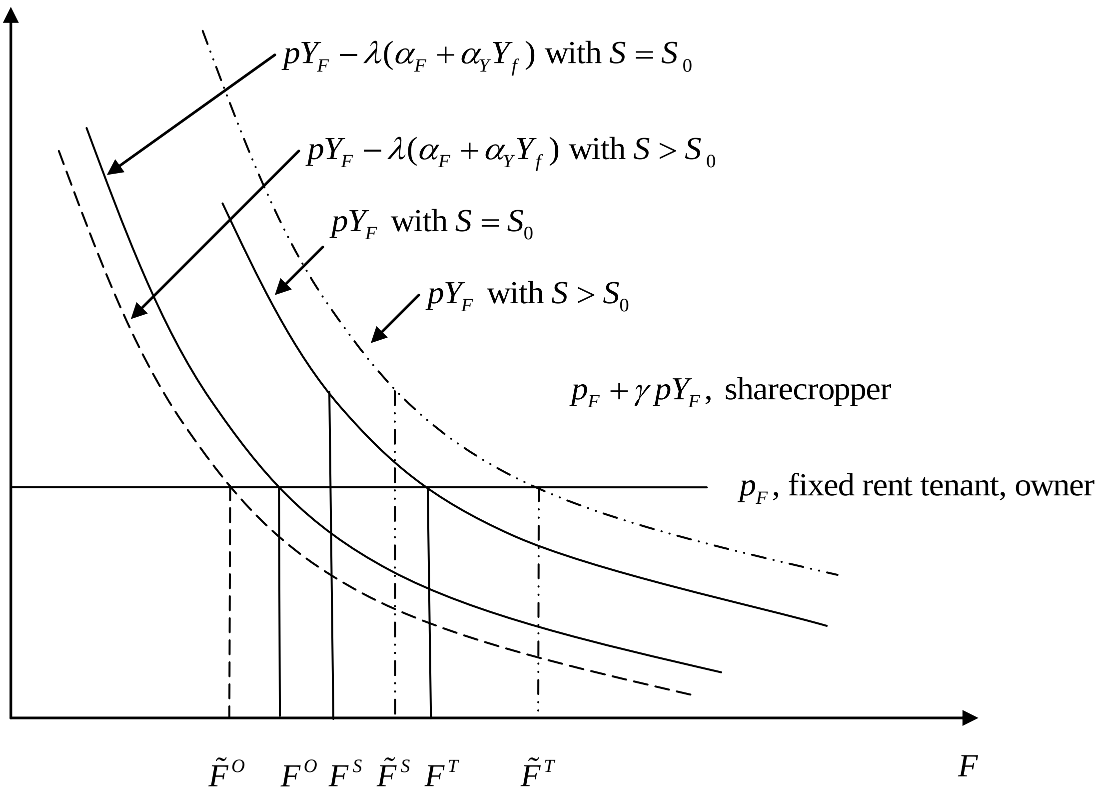

Figure 3: The optimal amount of mineral fertiliser

2. Empirical Analysis: Econometric Issues

The theoretical model provides general insights about the link between land tenure arrangements and the optimal investments behaviour. However, it does not account for socioeconomic factors and location specific information. Hence, we conduct an empirical cross-section analysis that accounts for this additional information and also allows us to contrast the results of our theoretical findings. The analysis focuses on the investment behaviour of farmers but does not consider the long-term perspective.

2.1 Land Tenure and Investment

The maximization problems for sharecroppers and fixed-renters outlined in equation (1) and that of owner-cultivators in equation (7) suggest that farmers invest in soil-improving and yield enhancing measures, if the resulting changes in the discounted aggregated stream of future farm profits is positive, i. e. $\partial J^{1} / \partial X$ is positive with $l = O, C$ and $X = M, L, F$. However, the information about this change is private and therefore not observable. What is normally observed is the decision to invest or not to invest in soil-improving and yield-enhancing measures. The empirical specification and analysis focus on the underlying factors that determine farmers' decisions to engage in soil-improving and yield-enhancing measures. Let's define the underlying latent propensity variable for investment in the soil-improving and yield-enhancing measures by farmer *i* with $i = 1, \ldots\ldots, N$ as I_i^*. Given the censored nature of the investment decision variable, the tobit specification can be employed in the analysis. This is given by

$$I_{im}^* = Z_{im}^{/} \varphi_{im} + X_{im}^{/} \psi_{im} + \mu_{im} \qquad i = 1, \ldots\ldots, N \tag{26}$$

$$I_{im} = \begin{cases} I_{im}^* \; if \quad I_{im}^* > 0 \\ 0 \quad otherwise \end{cases},$$

where *m* indicates the three different investment options in soil improving and yield-enhancing measures. While I_{im}^* represent the unobserved latent variable, I_{im} is observed, and φ_{im} and ψ_{im} are parameters to be estimated. We assume that the errors μ_{im} are independently and identically distributed. The vector X_{im} includes variables showing whether the land is owner-cultivated or cultivated under sharecropping or fixed-rent contract, while the vector Z_{im} includes household characteristics such as age, gender, and number of years of formal schooling of the farmer, as well as farm-specific characteristics such as farm size and geographic location.

As stated earlier, land tenure arrangements and investment decisions may be jointly determined, resulting in endogeneity of the land tenure variables in equation (26)[19].

Thus, the determinants of land rights may also be specified as

$$X_{im} = I_{im}\gamma_{im} + Z_{im}^{/}\delta_{im} + \xi_{im,} \quad (27)$$

where γ_{im} and δ_{im} are parameters to be estimated and ξ_{im} is an error term. Because of the censoring in the dependent variables, the empirical model used below is the form suggested by Smith and Blundell (1989). The authors develop both a test for endogeneity and an efficient method of estimation in the context of simultaneity and censoring. The test for endogeneity is developed by writing μ_{im} from (26) conditional on ξ_{im} from (27) as $\mu_{im} = \xi_{im}\phi_{im} + \upsilon_{im}$. Substituting μ_{im} into (26) then produces the conditional model

$$I_{im}^{*} = Z_{im}^{/}\alpha_{im} + X_{im}^{/}\beta_{im} + \xi_{im}\phi_{im} + \upsilon_{im} \quad (28)$$

A test of the null hypothesis $\phi_{im} = 0$ constitute a test for exogeneity of X_{im}; specifically, if the hypothesis that $\phi_{im} = 0$ is not rejected, then the hypothesis that land rights are an exogenous determinant of investment in productivity enhancing measures is not rejected. The test is implemented by first estimating (27) and then using the residuals from that estimation as estimates of ξ_{im} (28). Specification (28) is then estimated via a standard censored regression. If the coefficient on the residual term is significant, then exogeneity is rejected. Given that the dependent variables in (27) are discrete, we employ a linear probability model to facilitate estimation and computation of standard

[19] Jacoby and Mansuri (2008) also pointed out that most models of agrarian contracts imply a correlation between contractual choice and unobserved cultivator characteristics, resulting in endogeneity of land tenure arrangements.

errors in the second stage estimation. To account for second stage heteroskedasticity, is first estimated by OLS to obtain predicted values for land tenure variables and then is re-estimated with weighted least squares using the inverse of these predicted values as weights (Maddala, 1983).

Using the above method involves identifying a vector of excluded instruments. We employ a dummy variable indicating whether the landlord resides in the village where the farm is located or not and the distance of the farm from the landlord's residence as identifying instruments. The validity of the exclusion restriction can then be tested by the over- identification test statistic suggested by Lee (1992). This test statistics is distributed as χ^2 with degree of freedom equal to the number of excluded instruments.

2.2 Land Tenure and Farm Efficiency

Besides, analysing the impact of tenure arrangements on soil improving and productivity enhancing investments, we also employ a stochastic profit frontier model to examine the relationship between tenure security and profit efficiency. As profit efficiency is the ability of the farm to achieve the highest possible profit given the prices and levels of fixed factors of that farm, profit inefficiency in this context can be defined as the loss of profit from not operating on the frontier (see, for example, Jondrow et al. (1982); Battese and Coelli, 1995; Kumbhakar and Lovell, 2000).

We employ a translog functional form to estimate the profit function. This is a flexible functional form that places no *a priori* restrictions on the elasticity of substitution and allows the economies of scale to vary with the output level (Ali and Flinn, 1989). The normalized translog stochastic profit function, which is assumed to be "well behaved", is specified as[20]:

$$In\pi_i = \beta_0 + \beta_0^* D_i + \sum_n \alpha_n \ln p_{ni} + \sum_q \beta_q Inz_{qi} + \frac{1}{2}\sum_n \sum_l \alpha_{ni} Inp_{ni} Inp_{Li} +$$

$$\frac{1}{2}\beta_{qq}(Inz_i)^2 + \sum_n \gamma_{nq} Inp_{ni} Inz_{qi} + v_i + u_i \qquad (29)$$

[20] Competitive input and output markets are assumed because all output and input prices are exogenous to the farm household. The Cobb-Douglas specification was tested versus the Translog and rejected at the 1% level of significance.

where *i* indicates a specific farmer in the sample, π_i is the normalized profit computed as gross revenue less variable costs, D_i is a vector of dummy variables representing districts fixed effects; while p_{ni} is a vector of input prices with n representing the number of variable inputs. Inputs such as land and labor are captured by the vector z_{qi}, with $q = 1,2$. The v_i's are assumed to be independent and identically distributed random errors having $N(0, \sigma_v^2)$ distribution, while the u_i's reflect profit inefficiency. The determinants of inefficiency are specified as $u_i = \alpha_0 + \alpha_1 R_i + \alpha_2 X_i$ where R_i and X_i indicate a vector of household and farm-level characteristics, and a vector of tenure arrangement variables, respectively, as defined above. The $\alpha_i^{/}s$ are the parameter to be estimated. The parameters of the model are estimated in one stage with the approach proposed by Battese and Coelli (1995).

In estimating the translog function, we consider the specification as a second order approximation around the sample median, by normalizing all the variables by the corresponding sample medians[21]. The convexity of the estimated profit function implies that the profit function is a result of profit maximization. This assumption is reasonable in the present study because the sample only consists of cotton farmers, who produce for the market and therefore aim at maximizing their benefits from production. Hence, comparing profits among different farms can reveal the extent to which these farms achieve the objective of profit maximization.

3. Data and Description of Variables

The data employed in this study were collected with a survey of farmers from seven districts in the Punjab province in Pakistan. A stratified random sampling of 325 cotton farm households was selected from the Punjab province for the survey. The survey was conducted through questionnaire interviews by local enumerators who were trained prior to the exercise which took place between August and December 2007. The districts sampled include Bahawalpur, Bahawalnagar, Vehari, Khanewal, Multan, Lodhran and Rahim Yar Khan. The sample consisted of 210 owner-cultivated households, 88 households with sharecropping contracts and 27 household with fixed

[21] This stems from the fact that the translog functional form requires that the underlying profit function is approximated around a specific point. The median is chosen rather than the mean because it is less affected by outliers and as such more precise in the approximation of the translog.

rent contracts. The soil improving and productivity enhancing investments undertaken by farmers included organic (manure) and mineral fertiliser and planting of leguminous crops.

The survey gathered information on household and farm-level characteristics. Household variables included the number of years of schooling and the age of farmer, implements owned by farmer, livestock value and access to credit. Improved natural resource management practices such as mulching and manure preparation and application are knowledge-intensive and require considerable management input (Barrett et al., 2002). In particular, formal schooling may enhance latent managerial ability and greater cognitive capacity.

Differences across farms in term of quality and location also affect the suitability of the plots for various investments. Information on farm characteristics was therefore collected to address this issue. Farm-level variables included distance of the cultivated land (farm) from home for owner-cultivators, distance of farm from landlord's home for sharecroppers and fixed-renters, soil fertility, and slope of land. A farmer's decision to apply organic or mineral fertiliser or cultivate leguminous crops (green manure) will depend on whether the fertility of the soil needs to be replenished. The manpower availability is captured by the number of adults in the household while possible wealth effects are captured by including farm size, farm implements owned and livestock ownership. The age of the farmer is included to capture potential returns to experience.

To examine the impact of land tenure on efficiency, detailed information was also collected on quantities and prices of inputs such as seeds, pesticides, farm labor as well as farm output. Detailed information was collected on the amount of mineral and organic fertiliser applied and the number of acres used in the cultivation of leguminous crops. The dependent variable in the investment specification is censored, since some of the observations are zero. The descriptive statistics of the variables used in the analysis are provided in table 1. The statistics reveal that the mean value of output was highest for owner-cultivators, followed by fixed-renters and sharecroppers, respectively.

Table 1: Descriptive statistics of variables used in the empirical analysis

Variable	Description	Sample Mean	Standard Deviation
Total cost	Per hectare cost of cotton production in Rupees	17559	5766.5
Output value	Per hectare value of cotton output in Rupees	33937.7	1326.7
Cotton Price	Price of 40 kg cotton in Rupees	1537.7	307.2
Cotton area	Number of hectares under cotton cultivation	12.95	18.24
Profit	Per hectare profit from cotton output	16378	8920.5
Seed	Price of 1 kg seed in Rupees	92.13	23.57
Pesticide	Price of 1 liter pesticide in Rupees	312.8	241.23
Fertilizer	Price of 1 bag (50 kg fertilizer) in Rupees	724.4	254.62
Manure	Price of 1 troley farm yard manure in Rupees	387.08	339.46
Irrigation	Price of 1 irrigation in Rupees	377.10	255.84
Labour	A unit cost of labour per man day	112.2	154.23
Districts fixed effects			
Bahawalpur	1 if farmer belongs to Bahawalpur district, 0 otherwise	0.17	0.38
Bahawalnagar	1 if farmer belongs to Bahawalnagar district, 0 otherwise	0.10	0.29
Khanewal	1 if farmer belongs to Khanewal district, 0 otherwise	0.14	0.34
Vehari	1 if farmer belongs to Vehari district, 0 otherwise	0.16	0.36
Multan	1 if farmer belongs to Multan district, 0 otherwise	0.06	0.24
Lodhran	1 if farmer belongs to Lodhran district, 0 otherwise	0.18	0.39
Age	Age of cotton farmer in number of years	42	12.14
Education	Number of years of schooling	9.02	4.26
Owner	1 if land is under owner-operated, 0 otherwise	0.63	0.26
Sharecropper	1 if land is under sharecropping, 0 otherwise	0.27	0.24
Fixed-rent	1 if land is under fixed-rent, 0 otherwise	0.10	0.15
Soil fertility	1 if good soil fertility, 0 otherwise	0.46	0.49
Family size	Number of total family members	9.53	5.3
Road access	1 if household had road access, 0 otherwise	0.83	0.37
Family type	1 if joint family, 0 otherwise	0.78	0.4
Tubewell	1 if farmer owns a tube well, 0 otherwise	0.66	0.47
Organic Manure	Amount applied per hectare in kg	297	171
Mineral Fertilizer	Amount applied per hectare in kg	155	87
Leguminous crops	Number of hectares under leguminous crops	0.91	0.79
Pre-sowing irrigation	1 if farmer carried out double pre-sowing irrigation, 0 otherwise	0.46	0.49
Non-farm work	1 if farmer engaged in non-farm work, 0 otherwise	0.20	0.40
Extension contact	1 if farmer have contact with extension agent, 0 otherwise	0.81	0.40
Farmer field school	1 if farmer is member of farmer field school, 0 otherwise	0.16	0.36
Credit access	1 if farmer have access to credit facility, 0 otherwise	0.62	0.48

4. Empirical Results

4.1 Results of Land-Related Investments

The results of the (first-stage) regression of land rights on household and farm-level variables as well as the instruments used in the (second stage) investment regression are presented in table 2. The omitted category is the owner-cultivator variable and the specifications were estimated with a linear probability model. Household and farm characteristics appear to be related to the rights that household enjoy. The village effects reveal that two districts namely Bahawalpur and Rahim Yar Khan tend to favour owner-operated tenure arrangements. The F-test on the joint significance of the instruments (distance and location) in the land rights regression is reported in the table. The hypothesis that they are jointly zero is rejected at the 1% level of significance.

Table 2: Linear probability estimates of determinants of land tenure arrangements

Variable	Fixed-rent arrangement		Share-cropping arrangement	
	Coefficient	t-value	Coefficient	t-value
Farm size	-0.036**	2.08	-0.017	0.89
Soil fertility	0.286	1.63	0.024*	1.71
Slope	0.108*	1.98	0.262*	1.84
Tube well	0.013	1.18	0.049	0.83
Extension	0.076*	1.86	0.008*	1.97
Household size	-0.009	0.54	-0.082**	2.03
Female	-0.039	0.50	-0.061	0.71
Age	-0.009*	1.86	-0.017*	1.96
Education	0.022	0.73	0.031	0.96
Livestock	0.088***	2.72	0.045**	2.09
Implements	-0.049	1.52	-0.036	1.39
Years under cultivation	0.007*	1.92	0.058**	2.26
Distance from landlord	0.021***	2.38	0.015**	2.17
Location of farm	0.062***	2.51	0.138**	2.25
Bahawalpur	-0.452***	2.69	-0.081***	2.37
Bahawalnagar	0.038*	1.92	0.076*	1.84
Khanewal	0.006	0.57	0.022	0.68
Multan	-0.011	1.25	0.006	0.38
Lodhran	0.019	0.77	0.284	1.13
Rahim Yar Khan	-0.032***	2.56	-0.047*	1.92
F-Statistics	21.82		27.69	
[p-value]	[0.00]		[0.00]	

Note: The t-values are significantly different from zero at ***1%, **5% and *10% levels respectively.

The empirical results for the investment equation (28) are presented in table 3. It is clear from the results that the variables representing the residuals (RESSHARE and RESFIXED) derived from the first stage regression for fixed rent and sharecropping are not statistically significant at conventional levels, suggesting no simultaneously bias and that the coefficients have been consistently estimated (Wooldridge, 2002). Also shown in the table are the χ^2 - statistics for the joint Wald tests on the vector of these residuals. These values reveal that for each investment equation, the null hypothesis that the residuals are jointly equal to zero could not be rejected, again confirming the results of the individual t-statistics. These results are not surprising because in the study area, property rights to land are normally acquired either through purchase of land, inheritance or gifts. Contrary to other regions and countries individuals have few options to engage in activities that increase tenure security.

The coefficient of primary interest in table 3 are those on sharecropping and fixed-rent tenants. The specifications for organic fertiliser and leguminous crop show that the coefficient on sharecropping is negative and significantly different from zero, while positive and insignificant in the specification of mineral fertiliser. The computed marginal effects from the coefficients indicate that sharecroppers apply about 41% less organic fertiliser than owner-cultivators and devote 33% less land to the cultivation of leguminous crops[22]. The estimates of the coefficients on fixed-renters are also negative and significantly different from zero, while positive and significant in the specification for mineral fertiliser. The marginal effects indicate that fixed-renters apply almost 21% less organic fertiliser and devote 12% less land to the cultivation of leguminous crops, as compared to owner-cultivators. On the other hand, they apply almost 31% more mineral fertiliser than owner-cultivators, a finding that is consistent with the notion that fixed-renters normally attempt to maximise net benefits from their rented land within a very short time, which normally include applying relatively high levels of yield enhancing inputs such as mineral fertiliser.

It is significant to note that these empirical results are consistent with our theoretical findings, where we showed that owner-cultivators apply more organic fertiliser in the form of manure and cultivate more leguminous crops than fixed-rent tenants who in turn apply more organic fertiliser than sharecroppers, if the soil improvement effect is greater than the soil degradation effect of organic fertilizer. Hold-up problems in the

[22] To obtain the marginal effects within a Tobit model, the Maximum Likelihood Estimates must be multiplied by the proportion of non-censored observations in the sample (Greene, 2003), which is 57.7% within the data.

sense of lack of full commitment on the part of landlords could be influencing the findings for fixed-rent tenants and sharecroppers, since supervision, which is quite expensive in the study area, is not undertaken to ensure that tenants put in maximum effort in terms of investment in soil-improving measures and yield enhancing inputs.

Table 3: Tobit estimates of extent of investment in land improving measures

Variable	Manure	Fertilizer	Leguminous crops
Sharecropping	-0.718**	0.414	-0.581**
	(2.34)	(1.58)	(2.04)
Fixed-rent	-0.359***	0.534***	-0.213**
	(3.19)	(2.73)	(2.25)
Farm size	-0.017*	0.182**	-0.105*
	(1.68)	(2.69)	(1.76)
Soil fertility	0.759*	0.531*	-0.194
	(1.72)	(1.84)	(1.14)
Slope	0.246	-0.092*	0.057
	(1.43)	(1.85)	(1.39)
Tube well	0.102*	0.118	0.286
	(1.96)	(1.22)	(0.08)
Extension	0.503*	0.216	0.034**
	(1.87)	(1.57)	(2.03)
Household size	-0.085	-0.116*	-0.001
	(0.79)	(1.77)	(0.01)
Female	0.079	-0.061	-0.064
	(0.82)	(0.22)	(0.86)
Age	0.014**	0.036	0.032*
	(2.16)	(1.33)	(1.69)
Education	0.266*	0.042*	0.062*
	(1.78)	(2.14)	(1.87)
Livestock	0.864***	-0.041	0.263**
	(3.12)	(0.72)	(2.41)
Implements	0.266*	0.238*	0.316**
	(1.78)	(1.83)	(2.39)
Plot years	0.151***	0.329***	0.77**
	(3.74)	(4.02)	(2.16)
Bahawalpur	0.318**	0.577**	0.674***
	(2.01)	(2.26)	(2.56)
Bahawalnagar	0.548*	0.708	0.619**
	(1.69)	(1.57)	(2.01)
Khanewal	-0.205	0.204	0.374
	(0.34)	(1.22)	(1.35)
Multan	0.322	-0.847*	0.306
	(1.38)	(1.79)	(0.76)
Lodhran	0.159	-0.206	0.212
	(0.96)	(0.33)	(1.14)
Rahim Yar Khan	0.235**	-0.172	0.148*
	(2.36)	(0.64)	(1.87)
RESSHARE	0.043	0.038	0.19
	(1.08)	(1.26)	(0.62)
RESFIXED	0.278	0.154	0.138
	(0.96)	(1.02)	(1.17)
χ^2-statistics for overidentification	0.69 [0.43]	0.55 [0.49]	0.82 [0.51]
χ^2-statistics for joint significance of residues	0.962 [0.32]	0.782 [0.56]	1.06 (0.53)
Number of Observations	325	325	325

Note: Absolute t-values in parentheses and *p*-values in squared brackets.
***significant at 1%, **significant at 5%, *significant at 10%.

The observed positive effect of tenure security on investment in soil-improving measures is consonant with the notion that in the absence of security of tenure, farmers tend to be unsure about capturing future returns to investments that yield medium to long term net benefits and as such tend to invest less in such activities. In particular, the positive impact of ownership on the application of manure is consistent with the findings of other studies such as Gavian and Fafchamps (1996) for Niger and Jacoby and Mansuri (2008) for rural Pakistan. Gavian and Fafchamps (1996) point out that in the presence of perfect markets for manure, individuals unsure about capturing future returns to manuring would be better off selling the manure to secure households than applying on rented land.

The variable representing farm size is positive and significantly different from zero for mineral fertiliser but negative and significant for organic fertiliser and leguminous crops. Thus, as farm size increases, it may become less feasible for the farmer to meet the farm yard manure requirement of the land under cultivation, a finding that is consistent with Deininger et al. (2009) for Ethiopia. Livestock ownership is shown to exert a positive and significant effect on manure and leguminous crops but no significant influence on the application of mineral fertiliser. The positive and significant influence of livestock ownership is in agreement with the idea that farmers have manure resources that are largely determined by their possession of animals. Investment in organic manure and fertiliser are higher on fertile land, where the returns to such investments are likely to be much higher.

Access to extension services is found to have a positive and significant effect on investments in organic fertiliser and leguminous crops. The coefficient for age is positive for all three types of investments, although statistically significant only for organic fertilizer and leguminous crops, suggesting that older farmers invest more in soil improving and yield enhancing measures. The results also appear to suggest the presence of wealth effects as the farm implements turned out to be positive and significantly different from zero for all three investment options. In particular, investments in mineral fertiliser and cultivation and ploughing of leguminous crops into the soil require significant cash outlays. Higher levels of education also increase the propensity to invest in both soil improving and yield-enhancing measures. Farm land that has been under cultivation for long periods receives higher levels of manure and fertiliser as well as acreage used for leguminous crops.

A number of the district dummies are significantly different from zero. Moreover, the joint test of the null hypothesis that all district effects are equal using a likelihood ratio test given a sample χ^2 value of 67.26 against a critical value 16.7 at the 1% level of significance. This suggests the presence of significant cluster effects, and probably reveals agro climatic variation and access to infrastructure. The finding could also differences in district level land tenure arrangements (Besely, 1995).

4.2 Land Tenure and Farm Efficiency

The maximum-likelihood (ML) estimates of the normalized profit frontier subject to the restrictions of homogeneity and symmetry are given in table 4. The equation was estimated by Frontier 4.1, an econometric package developed by Coelli (1996). A glance at the results in table 4 indicates that land has the expected positive sign; while the coefficient for the prices of seed and labour has the expected negative signs. The estimates of sources of inefficiency are also presented in table 4. The results show that tenancy arrangements do influence efficiency. Specifically, coefficients for the variables sharecroppers and fixed-renters are positive and significantly different from zero, indicating that owner-cultivators are more efficient compared to sharecroppers and fixed-renters.

The level of education (human capital) of the farmer tends to have a positive and significant impact on profit efficiency. Household size, which reflects the household manpower resources, has a significantly positive influence on efficiency, a finding that is in contradiction with allocative efficiency. Thus, labor transactions may be failing to make up for differences in land endowments. Quite a number of studies have demonstrated that household manpower resources and other characteristics tend to influence returns to farming in different institutional settings, suggesting that factors are not efficiently allocated across farms (e.g. Gavian and Fafchamps, 1996; Ali and Flinn, 1989; Parikh et al., 1995). Other variables such as access to irrigation, contacts to extension services and access to credit all tend to have statistically positive influences on efficiency. The positive impact of access to credit indicates that farmers who face financial constraints on purchased inputs experience profit inefficiency.

Table 4: Maximum likelihood estimates of translog profit frontier

Parameter	Variable	Coefficient	t-ratio
β_0	Constant	1.552***	13.538
β_1	ln (land)	1.176***	2.472
β_2	ln (seed)	-0.106**	-1.984
β_3	ln (pesticide)	0.472	0.819
β_4	ln (fertilizer)	0.535	0.948
β_5	ln (manure)	-0.436	-0.812
β_6	ln (labour)	-0.726***	-2.554
β_7	ln (land) x ln (land)	0.903*	1.785
β_8	ln (seed) x ln (seed)	0.616	0.719
β_9	ln (pesticide) x ln (pesticide)	0.417	1.276
β_{10}	ln (fertilizer) x ln (fertilizer)	0.332*	1.909
β_{11}	ln (manure) x ln (manure)	-0.155	-0.181
β_{12}	ln (labour) x ln (labour)	0.264**	2.139
β_{13}	ln (land) x ln (seed)	0.023**	2.166
β_{14}	ln (land) x ln (pesticide)	-0.049	-0.791
β_{15}	ln (land) x ln (fertilizer)	0.102	0.792
β_{16}	ln (land) x ln (manure)	0.057	1.044
β_{17}	ln (land) x ln (labour)	-0.169***	-2.472
β_{18}	ln (seed) x ln (pesticide)	0.211*	1.714
β_{19}	ln (seed) x ln (fertilizer)	0.257*	1.669
β_{20}	ln (seed) x ln (manure)	-0.212***	-3.161
β_{21}	ln (seed) x ln (labour)	-0.323***	-2.734
β_{22}	ln (pesticide) x ln (fertilizer)	-0.089	-0.305
β_{23}	ln (pesticide) x ln (manure)	0.104*	1.782
β_{24}	ln (fertilizer) x ln (labour)	0.590**	2.109
β_{25}	ln (fertilizer) x ln (manure)	0.189*	1.687
β_{26}	ln (fertilizer) x ln (labour)	0.121	0.454
β_{27}	ln (manure) x ln (labour)	-0.057	-0.594
Variance parameters			
σ^2	$(\sigma^2 = \sigma_u^2 + \sigma_v^2)$	2.458***	3.744
γ	$(\gamma = \sigma_u^2 / \sigma_u^2 + \sigma_v^2))$	0.995***	246.895
Inefficiency effects			
δ_0	Constant	-0.728	-0.407
δ_1	Age	0.025	1.587
δ_2	Education	-0.071**	-2.334
δ_3	Family size	-0.088**	-2.065
δ_4	Tube well	-0.057*	-1.934

Table 4 (continued)

Parameter	Variable	Coefficient	t-ratio
δ_5	Road access	-0.149***	-2.411
δ_6	Family type	-1.143*	1.826
δ_7	Soil fertility	-0.710***	-2.644
δ_8	Credit access	-0.231*	1.810
δ_9	Off-farm work	-0.561	-0.903
δ_{10}	Pre-sowing irrigation	0.540	1.217
δ_{11}	Extension contact	-1.224*	-1.723
δ_{12}	Sharecropper	2.117*	1.827
δ_{13}	Fixed renter	3.451**	2.124

Note: District dummies included in the model but not reported. *, **, *** indicates significance at 10%, 5% and 1% levels, respectively. A positive sign of a parameter of the inefficiency model means that the associated variable has a negative impact on technical efficiency, and a negative sign indicates the reverse is true.

Although, the results of the determinants of inefficiency show that owner-cultivated lands are more efficient than fixed-rent and sharecroppers, they do not show the differences between fixed-rent and sharecropping in terms of efficiency. Table 5 therefore presents estimates of technical, allocative and economic efficiency for the various tenancy arrangements[23]. The estimates reveal that owner-cultivated lands exhibit the highest levels of technical, allocative and economic efficiency followed by fixed-renters and sharecropper showing the lowest level of efficiency. On average, the allocative efficiencies for owner-cultivators fixed-renters and sharecroppers are 92, 85 and 82 while the corresponding figures for technical efficiency are 86, 80 and 77, respectively. The findings indicate that on average, the efficiency of owner-cultivators differs little from that of fixed-renters and sharecroppers. However, the minimum and maximum efficiency levels reveal that the average conceals considerable heterogeneity across tenure regimes. For example, while the minimum and maximum levels of allocative efficiency for owner-cultivators are 58% and 99%, respectively, the corresponding figures for fixed-renters are 36% and 91%, and for sharecroppers, 27% and 89%, respectively. These results suggest that redistribution of land in favour of both sharecroppers and fixed-renters could have considerable efficiency effects.

Table 5: Efficiency levels among owner-cultivators, sharecroppers and fixed-renters

Efficiency Category	Owner-cultivator			Sharecropper			Fixed renter		
	Average	Max	Min	Average	Max	Min	Average	Max	Min
Technical Efficiency	0.86	0.94	0.45	0.77	0.84	0.26	0.80	0.88	0.32
Allocative Efficiency	0.92	0.99	0.58	0.82	0.89	0.27	0.85	0.91	0.36
Economic Efficiency	0.78	0.98	0.27	0.62	0.77	0.13	0.68	0.84	0.21

[23] Technical efficiency was estimated with a translog stochastic frontier production function.

Although our results show that investment in soil improving measures is affected by tenure security, it is also significant to examine the relationship between investments and efficiency before we can conclude that efficiency is reduced by tenure concerns. We therefore employed a propensity score matching approach to examine the direct effects of investments in organic and mineral fertiliser and leguminous crops on farm productivity and efficiency. Table 6 presents the average treatment effects (ATT) estimated by nearest neighbour matching (NNM) and kernel-based matching methods (KBM). The matching results from both approaches generally indicate that investment in organic and mineral fertiliser and leguminous crops exert a positive impact on farm productivity and efficiency, indicating that this may partly account for the productivity and efficiency impacts of tenure security.

Table 6: Average treatment effect for organic manure, fertilizer and leguminous crops

	Organic Manure		Fertilizer		Leguminous crops	
	NNM	KBM	NNM	KBM	NNM	KBM
Yield (kg/ha)	80* (1.71)	88* (1.74)	73* (1.84)	76* (1.69)	101*** (3.28)	112*** (3.05)
Technical efficiency	0.127*** (2.49)	0.109* (1.94)	0.139*** (3.78)	0.158*** (4.15)	0.15* (1.73)	0.17** (2.02)
Allocative efficiency	0.128** (2.18)	0.087 (1.22)	0.108** (2.27)	0.090* (1.85)	0.09* (1.82)	0.11** (2.25)
Number of treated	208	206	144	144	249	249
Number of control	113	113	176	177	25	25
Common support imposed	Yes	Yes	Yes	Yes	Yes	Yes
Balancing property satisfied	Yes	Yes	Yes	Yes	Yes	Yes

Note: Number in parentheses are t-values. Values are significantly different from zero at ***1%, **5% and *10% levels. ATT is the average treatment effect for the treated. NNM stands for Nearest Neighbour Matching and KBM stands for Kernel Based Matching.

5. Conclusions

This paper addresses the impact of land tenure arrangements on farmers' investment decisions in soil improving and yield enhancing measures as well as economic efficiency using a sample of 325 cotton farmers from the Punjab province in Pakistan. We observed wide variations in land tenure arrangements across the sampled farmers, as well as their investments in soil-improving and yield enhancing measures. Given that most models of agrarian contracts imply a correlation between contractual choice and unobserved cultivator characteristics, we employ a framework that accounts for potential land tenure endogeneity in our investment specification. We also employ a stochastic frontier model to examine the relationship between tenure security and farm efficiency.

We find robust evidence that secured land rights do matter when farmers make investment decisions about soil improving measures such as organic manure and cultivation of leguminous crops. Specifically, farmers with secured land rights are found to be more likely to invest in soil improving measures, compared to those on leased contracts. However, tenure security does not matter for investments in short-term yield enhancing inputs such as mineral fertiliser, since fixed-rent tenants are found to apply higher levels than owner-cultivators.

While both moral hazard and hold-up problems may explain the lower levels of investment by sharecroppers, the finding for fixed-renters may be attributed whereby landlords do not fully commit to their contracts with fixed-renters. Under such conditions, fixed-renters do not find it attractive to invest in long-term soil improving measures; since the landlord could decline to extend the contract once it expires, preventing the tenant from reaping the benefits of the investments.

We also find empirical support for the hypothesis that farmers with secured land rights are more efficient than those with leased contracts. Specifically, the average allocative efficiencies for owner-cultivators, sharecroppers and fixed-renters are 92%, 82% and 85%, respectively. Although these average efficiency differences between owner-cultivators and those of tenants do not appear to be large, the averages actually concede great heterogeneity across tenure arrangement types. The higher levels of efficiency on owner-cultivator farms stem from their higher incentive to invest in soil improving and productivity enhancing measures, and to exert great effort in production. Given the high cost of supervision in Pakistan, landlords rarely supervise their share-tenants, resulting in tenants exerting less effort and therefore achieving lower productivity levels. These findings generally suggest that a land redistribution exercise in favour of sharecroppers and fixed-renters could have considerable efficiency effects. We also employed a propensity score matching model to assess the impacts of investments in soil improving and productivity-enhancing measures on farm productivity and efficiency. The findings revealed that investment in organic fertiliser, mineral fertiliser and leguminous crops exert positive impacts on farm productivity and efficiency, suggesting that investment in these soil-improving and yield-enhancing measures may partially account for the productivity and efficiency impacts of tenure security. Overall, our results indicate that redistribution of land that strengthens tenure security can have substantial investment and efficiency effects in agricultural production.

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Chapter 5

Farmers Access to Markets: The Case of Cotton in Pakistan

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Chapter 5

Farmers Access to Markets: The Case of Cotton in Pakistan

Abstract

This article examines cotton farmers' market participation and determinants of market participation by employing a cross-sectional data set from a survey of farmers in the Punjab province of Pakistan. A number of different econometric models were employed to carry out the analysis. The Probit model was employed for farmers' cotton selling decision making (market or farm gate) and the Heckman selection estimator was employed to correct for sample selection bias for the quantity of cotton sold at the market. For the distance travelled to sell cotton both Tobit and censored least absolute deviation (CLAD) models were employed. The CLAD model along with the Tobit model was employed because the CLAD model is flexible and takes the heteroscedasticity and non normality assumptions into account. Generally, the findings reveal that households owning more human and capital resources like having more education, wealth and transport facility have easy access to markets. In contrast, as the distance to market increases the household prefers to sell at the farm gate. Besides village infrastructure and socioeconomic characteristics of the household, an important role is played by the informal credit source, i.e. local traders (commission agent) in determining cotton farmers' market participation. The propensity score matching approach was employed to estimate cotton net returns. The results indicate that net returns are higher for farmers selling at the market compared to farmers selling at the farm gate in all the matching algorithms. Regarding policy implications, the study findings highlight the need for more investment in human capital development and infrastructure improvement so that cotton farmers have easy access to markets since currently, only large and resourceful farmers have easy access to markets and vice versa.

Key words: Cotton, Farm gate, Market, Transaction costs, Punjab, Propensity score matching

1. Introduction

Efficient marketing plays a crucial role in the process of economic development (Barrett and Emelly, 2005; Gideon et al., 2007; Kleih, 1999). In developing countries, the marketing system is mainly confronted with multiple problems like high transaction costs, poor physical and institutional infrastructure, lack of market information and inadequate markets (Jones, 1996). In Pakistan, first steps towards liberalising the export trade were taken in 1987 when exporting was opened to the private sector for the first time since 1973. Between 1973 and 1987, external trade was monopolised by the Cotton Export Corporation (CEC), a government controlled parastatal, which in addition to its role as the sole exporter was also responsible for maintaining a minimum support price for suppliers of seed cotton (growers) and suppliers of cotton lint (ginners). However, the CEC never played a significant part in the procurement of seed cotton as the support price tended to lie beneath the market price. Private traders have always dominated this part of marketing chain, acting as the main link between growers and the ginning factories. By 1993-94, the CEC was in serious financial difficulty and it has not purchased cotton since then. Since 1994, all exports have been in the hands of the private sector and in February 1995, the government removed all remaining duties and restrictions on the export of cotton (Lohano et al., 1998).

Regarding cotton marketing in Pakistan, the household financial condition plays a crucial role in deciding the place of cotton sale, i.e. the market or the farm gate. If the farmer is financially well-off, credit is not needed from informal sources and he does not have to buy inputs on credit. But the majority of cotton producers need credit during cotton season to meet the high input demand of the cotton crop or to buy inputs on credit from a local trader (commission agent), interlocking to sell cotton to local trader/ commission agent[24]. However, there exists the formal credit programme in the cotton growing areas of Pakistan but unfortunately, the formal credit programme is not very effective as the procedure is lengthy, the mark up rate is extremely high and also not in favour of small farmers[25]. Landless farmers are deprived of the credit facility from the formal sources due to no land ownership[26]. Because of these procedural and institutional problems, the farmers turn to informal credit source i.e. local traders

[24] The interlocking of input supply, credit and crop marketing is a common feature of marketing in many developing countries in Asia (Smith et al. 1999).
[25] In most cases only the wealthy and influential farmers are able to gain access to loans from formal sources.
[26] Because land is used as a medium of guarantee, the sharecropping or landless households gain even less access to formal sector credit (Smith et al. 1999).

(commission agent) since they provide ready credit[27]. These traders usually operate year round, buying cotton in winter season and wheat in summer season[28]. Many also supply credit and farm inputs, usually interlocking the supply of credit with a commitment on the part of the grower to sell his output to the trader[29] (commission agent). Commission agents and other traders are the major source of informal credit for small farmers in Pakistan[30] (Lahano et al., 1998). Availability of credit is a key issue in marketing in Pakistan, as the formal sector has generally failed to meet the farmers demand and it is the informal sector which meets the 70-80% of credit demands (Lohano et al., 1998). The majority of the farmers in Pakistan have no access to interlinked markets and have to deal with middlemen rather than direct sources[31] (Kamdar, 1990).

In Pakistan, the private sector has always played a significant role in credit provision, input distribution, and output marketing in rural areas. The lack of market information often deprives the farmers from their genuine right and causes them financial loss, so the cotton farmers have no other option except to sell on the rates offered by the local middleman/ commission agents (Khan, 2003). In addition to price, there are also other factors which affect farmers' decision regarding the selling place, Vakis et al. (2003) pointed out that farmers' decision where to sell a particular crop depends not only on the price they receive in each market but also on additional costs related to transacting in these markets. Similarly, Mcleay and Zwart (1988) have indicated that the farmer's sale transaction choice is influenced by marketing competencies and strategy, farm and farm manager's characteristics.

In the past, most of the literature on agricultural marketing has focused on the transaction costs and their affect on crop production (Allene et al*.,* 2008; Buduru and Brem, 2007; Dyer et al*.,* 2006; Renkow et al*.,* 2004; Obare et al*.,* 2003; Nigel et al*.,* 2000; Smith et al*.,* 1999; Fuentes, 1998). Fohad and Dina (2007) pointed out that focus on transaction costs was mainly on the transportation costs, but in the current

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27 Traders frequently act as moneylenders and input suppliers as well as providing crop marketing services (Smith et al., 1999).

28 The contracts between farmer and trader are informal and verbal in nature (Smith et al. 1999).

29 Another school of thought, drawing particularly evidence from South Asia, see interlocking of transaction as providing traders with a powerful means of extracting surplus from poor and vulnerable peasants (Smith et al. 1999).

30 The observed interest rates are quite high and vary in the range of 40-80 % per year.

31 Since sharecroppers are not greatly involved in crop marketing or the purchase of farm inputs, this is generally left to the owner. As a consequence, cotton is always marketed by the owner (Smith et al. 1999).

market participation scenario there are many other important factors which contribute to market participation besides transaction costs[32]. Chowdhury (2005) has observed that market participation was 14% higher in the case of the Bangladeshi farmers who have access to telephone compared to non users of phone. This indicates that overall improvement in the infrastructure index leads to greater market participation besides the financial condition of the farmer. Similarly, Holloway and Lapar (2003) have investigated the positive neighbourhood impact in market participation among Filipino smallholders.

According to Smith et al. (1999), the transaction costs normally include the following costs.

-*Search costs*: the costs of searching out suppliers or buyers in a particular market (for input, output or credit).
-*Screening costs*: the costs of establishing the reliability and trustworthiness of potential parties to a transaction particularly the creditworthiness of borrowers.
-*Negotiation costs*: the costs of measuring attributes such as quality and quantity of goods or services being bought or exchanged.
-*Transfer costs*: including transport, processing, packaging and securing title.
-Monitoring costs: the costs of monitoring whether the terms and conditions agreed on are fulfilled.
-*Enforcement costs*: the costs of enforcing agreement, of seeking compensation when an agreement is broken, or the cost incurred when a contract is broken.

The importance of farmers associations and cooperatives can not be ignored, but mostly these exist in small numbers and are handicapped by low quality of inexperienced management, thus not contributing to farmers in a benefiting way (IFAD, 2007).

[32]Transaction costs can be classified as the information, negotiation, and monitoring and enforcement costs. Information costs (ex-ante) relates to the costs incurred in obtaining information relative to the undertaking of the transaction (price information, market location etc.). Negotiation costs represent the costs incurred while the transaction is being carried out (negotiation terms of exchange, drawing up the contract, etc.). Monitoring and enforcement costs (ex-post) are the costs incurred once the transaction is completed and in order to ensure that the terms agreed upon ex-ante are kept to (payment arrangement).

Recent studies have focused on the factors influencing farmers' decision regarding marketing[33] (Jacoby, 2000; Fafchamp and Shilpi, 2003; Fafchamp and Hill, 2005; Fohad and Dina, 2007; Bellemare and Barrett, 2006). These studies' findings indicate that farmers lack access to markets, capital, inputs, new technology and extension services but farmers can be linked to markets through cooperatives, growers association and contract farming to reduce marketing and transaction costs (Pratap et al., 2007). A household's ability to access commodity markets has a significant impact on the crop share and the farm income since market participation can help to reduce poverty to a considerable extent (Zeller et al. 1998). In the present study effort has been made to investigate the factors influencing cotton farmers' market participation.

1.2 Cotton Marketing Chain in Pakistan

The cotton marketing chain in Pakistan is presented in figure 1. There are three principal actors in the marketing chain of seed cotton in Pakistan; farmers, local traders, and cotton ginners. The majority of seed cotton is sold by farmers to local traders (commission agent) who then sell it to cotton ginners, while some farmers travel to the market or directly sell to the ginning factories. Cotton ginning factories[34], located throughout the main production areas, process seed cotton into lint and cotton seed. The lint is sold via broker either to spinners located in large urban centres or to exporters. The seed is sold, again via brokers, to oilseed factories that produce cotton seed oil and seed cake. The main function of the ginners is processing, but they also provide credit services to local traders and farmers[35]. This is usually on interest free basis. The main purpose of lending from the ginners point of view is to have a mean of securing supplies.

This article is structured as follows. Section 2 explains the conceptual framework. Section 3 provides a description of the data and definition of the variables. The empirical results are presented in section 4 and in the final section 5 concluding remarks are presented.

[33] Farmers' decision whether to sell at the farm gate or to transport their produce to the market has received little attention in the literature (Fafchamps and Hill, 2005).

[34] The cotton price agreement between the trader and the factory either takes place over the phone, especially in the case of more distant factories, or is made at the factory itself. The agreement is normally made within a few days of purchasing agreements between the local traders and farmers. It states the volume of seed cotton to be delivered and the price per maund (1maund=40 kg). The agreement is an informal one, but once agreed, it is morally binding. Neither party is expected to seek a re-negotiation of the price.

[35] This facility from ginning factories is provided to a very limited number of traders and cotton farmers.

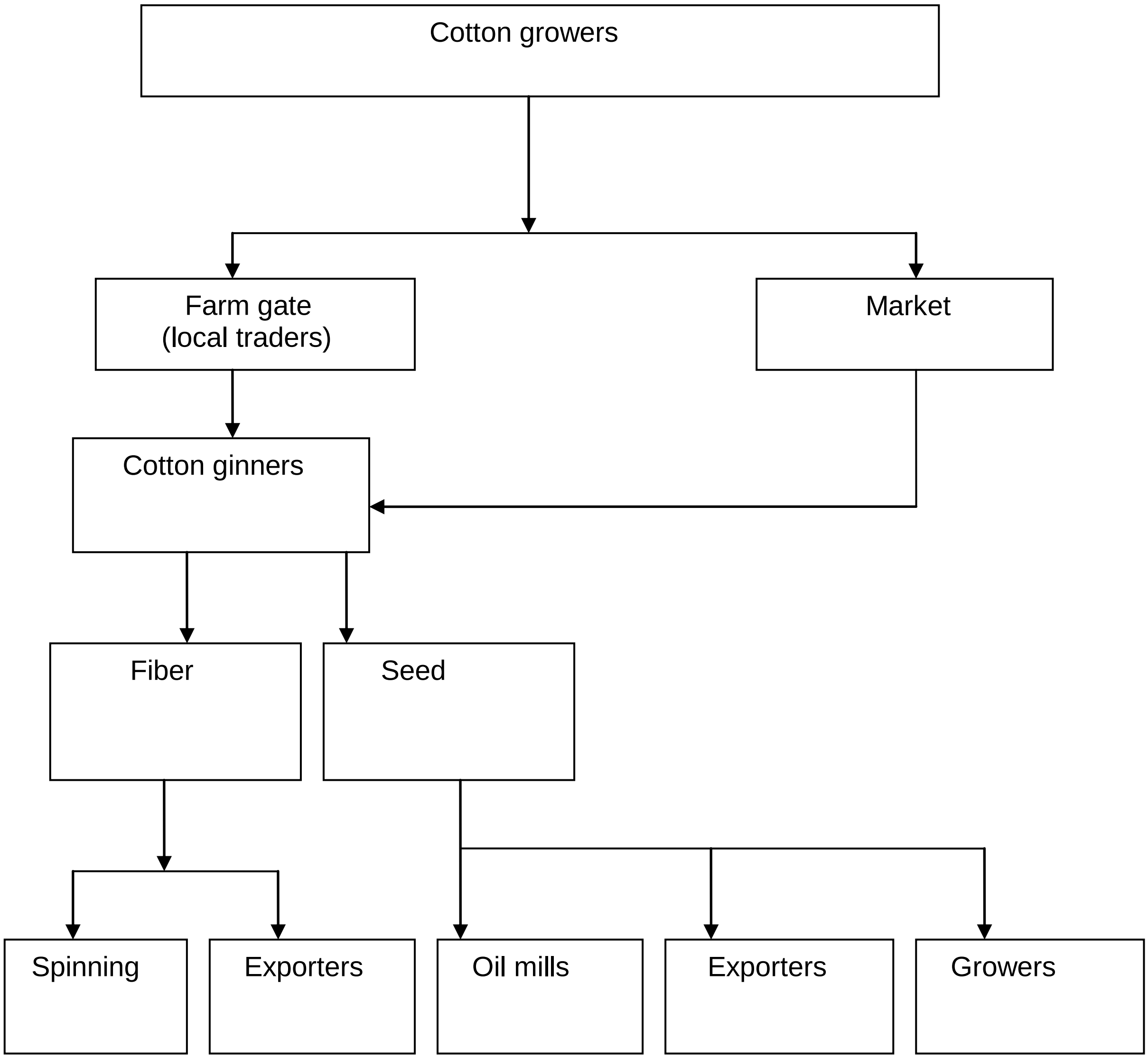

Figure 1: Cotton marketing chain in Pakistan.

2. Conceptual Framework

The conceptual framework presented in this study is inspired by two studies, i.e. Fafchamps and Hill (2005) entitled "Selling at farm gate or travelling to market" and Abdulai and Birachi (2008) entitled "Choice of coordination mechanism in the Kenyan fresh milk supply chain."

The starting point can be a simple model where a farmer can either sell at the farm gate or take the produce to the market. The price the farmer receives at the farm gate can be represented as p^f, whereas the price the farmer receives at the market can be represented as p^m. It is assumed that the price the farmer receives at the farm gate[36] (p^f) is lower than the price the farmer receives at the market[37] (p^m), but in the market the farmer has to face higher transaction costs *X*. Assuming a perfectly competitive market, a price-taker farmer *i* thus chooses to sell at the farm-gate if:

$$p^f \geq p^m - X_i \qquad (1)$$

Note that the transaction cost[38] *X* is assumed to be farmer-specific as has been emphasized in large literature on farm household's choices [de Janvry et al., 1991) and Key et al. (2000)]. Let the difference between the payoffs from selling at the market and selling at the farm gate be

$$D_i = p^m - X_i - p^f \qquad (2)$$

Factors that raise D_i will increase the sale at the market as opposed to the farm gate and vice versa.

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[36] Selling at the farm gate often is less remunerative but it may be the only alternative for the farmers who cannot afford carrying their crop to the market, usually located many miles away (Fafchamps and Hill, 2005).

[37] Since cotton is a cash crop, we can ignore the situation in which farmers wish to keep more cotton for home use and $p^f > p^m$.

[38] The problem with the explicit introduction of transaction costs into economic analysis is that transaction costs are difficult to measure in the real world. Little empirical estimation of transaction costs can be found in current literature, even more so in developing countries.

The villages are also served by itinerant traders (local traders/commission agents) who face transaction costs *T* to transport and sell the produce at the market. Free entry into itinerant trading implies that in equilibrium:

$$p^f = p^m - T \quad (3)$$

The difference between the payoffs from selling at the market and at the farm-gate can be re-defined as:

$$D_i = T - X_i \quad (4)$$

A farmer would choose to sell at the market, if $D_i \geq 0$ and vice versa.

It is assumed that farmers maximize their expected utility by choosing the place of sale with the highest perceived net returns, while facing the fixed (X_i^f) and proportional transaction costs (X_i^p). Fixed transaction costs are independent of the quantities transacted. These costs include searching for potential buyers and obtaining information about prices and markets etc. On the other hand, proportional transaction costs vary according to the quantity transacted and include price premiums obtained from bargaining capacity as well as per unit transport costs to the market.

Travelling to the market is associated with fixed and proportional transaction costs. The proportional transaction costs (X_i^p) are a function of distance and time to reach the markets. The proportional transaction costs can be denoted as $X_i^p = X^p(Z_i^p)$, where Z_i^p denotes a vector of factors such as distance, time and effort it takes to reach the market for cotton selling. For example, the transaction costs faced by the farmer will increase with the distance from the market. However, the individual transactions that occur in the market are associated with fixed transaction costs X_i^f that are invariant to the quantity transacted. This can be expressed as $X^f = X^f(Z_i^f)$, where Z_i^f is the vector of characteristics that influence fixed transaction costs.

Let Π_{im} be the net returns defined as total returns less fixed and proportional transaction costs, and P_i is the price realized from transaction *i* at a given place of sale, i.e. the farm gate or the market.

$$y_i = \arg\max\{\Pi_i = Q_i(P_i - X_i^p) - X_i^f(Z_i^f)\} \quad (5)$$

Equation (5) shows that forces that affect X_i^p and X_i^f certainly influence the level of Π_i and therefore the profit maximizing behaviour of cotton farmers. The equation can therefore be used to explore the role of transaction costs on the choice of place of sale, i.e. the farm gate or the market. Given that farmers are assumed to choose a given place of sale, either the market (y) or the farm gate (k), it is implied that:

$$\Pi_{iy} > \Pi_{ik}, \forall y \neq k \quad (6)$$

However, the net returns associated with each place of sale can be represented by their latent net returns, Π_i^*, such that the observed place of cotton sale represents the maximum possible latent net revenues available to the cotton farmer. Assuming that the place of sale can be represented by one and zero otherwise, the threshold measurement model for the place of sale can be formulated as:

$$\Pi_{im} = \begin{cases} 1 \, if \ \Pi_{iy}^* > \Pi_{ik}^* \\ 0 \, if \ \Pi_{iy}^* \leq \Pi_{ik}^* \end{cases} \quad \text{for all } y \neq k \quad (7)$$

where *y* and *k* represent the place of sale at the market and the farm gate, respectively. Equations (5) and (7) can then be utilized to specify the market participation model as follows.

$$y_i = \max(\Pi_i^* = R_i \beta^/ + W_i \phi m + \varepsilon_i) \quad (8)$$

where Π_{im}^* are the latent net returns from transaction *i* at a given place of sale, R_i is a vector of transaction costs' characteristics that influence the choice of the cotton selling place, W_i are socioeconomic and firm-related attributes that also influence the choice of the selling place, $\beta^/$ and ϕm are parameters to be estimated and ε_i are i.i.d. error terms.

2.1 Cotton Marketing Analysis

2.1.1 Cotton Farmers Market Participation

Consider a process with two possible outcomes, indicated by a dependent variable *'y'*, labelled for convenience *y*=1 and *y*=0. We assume as well that there is a set of measurable covariates, *x*, which will be used to help for explaining the occurrence of one outcome or the other. Most models of binary choice set up in this fashion will be based upon an index function, $\beta^{/} x$, where β is a vector of parameters to be estimated. The modelling of discrete binary choice in these terms is typically done in one of the following frameworks.

Thus, the probit model which forms the basis of most of the results in econometrics is based on a latent regression model in which the disturbances are assumed to have a normal distribution.

Based on normal distribution the probit model can be written as

$$\int_{-\infty}^{\beta^{/} x_i} \frac{\exp\left(-t^2/2\right)}{\sqrt{2\pi}} dt = \Phi\left(\beta^{/} x_i\right) \tag{9}$$

2.1.2 Instrumental Variable Approach

The instrumental variable method is possible when a variable can be identified to be related to participation but not to outcomes. This variable is known as the 'instrument' and it introduces an element of randomness into the assignment which approximates the effect of an experiment. Where variation in the impact of treatment across people is not correlated with the instrument, the IV approach recovers an estimate of impact of treatment on the treated (TT). The main drawback of the IV approach is that it is often is difficult to find a suitable instrument because, to identify the treatment effect, one needs at least one regressor which determines the programme participation but is not itself determined by the factors which affect outcome.

2.1.3 Censored Regression Model (Tobit Model)

The Tobit model is employed to capture the intensity of the density to the market. The censored regression or tobit model is appropriate when the dependent variable is censored at some upper or lower bound as an artifact of how the data are collected (Tobin 1958; Maddala 1983). For censoring at a lower bound, the model is

$Y*_{li} = X_i\beta + \varepsilon_i$, with (10)

$Y_{li} = Y*_{li}$ if $Y*_{li} > 0$ (11)

$Y_{li} = 0$ if $Y*_{li} \leq 0,$ (12)

where, for the *i*th observation, $Y*_{li}$ is an unobserved continuous latent variable, Y_{li} is the observed variable, X_i is a vector of values on the independent variables, ε_i is the error and β is a vector of coefficients. We assume that ε_i is uncorrelated with X_i and is independently and identically distributed. The censoring point may also vary across observations, leading to a model that is formally equivalent to models for survival analysis (Kalbfleisch and Prentice, 1980; Lancaster, 1990).

Unlike the standard estimators of the censored regression model such as Tobit or other maximum likelihood approaches, the CLAD estimator is robust to heteroscedasticity and is consistent and asymptotically normally distributed for a wide class of error distributions.

2.1.4 Heckman Selection Estimator

This approach has been extensively used in evaluations. It allows for selection into the treatment group on the basis of variables that are unobservable to the analyst. It operates by assuming a particular form for the distribution of the unobservable characteristics that jointly influence participation and outcome. By explicitly modelling the participation decision, it is possible to derive a variable that can be used to control for that part of unobserved variation in the outcome equation that is correlated with the unobserved variation in the participation decision. Including this new variable alongside the observable variables in the outcome equation can result in unbiased estimates of the treatment effects. While not strictly necessary from a mathematical viewpoint, credible implementation includes an instrument; that is, a variable included in the estimation of the participation equation that is excluded from the outcome equation.

This approach appears to offer an elegant means of obtaining an estimate of TT in the presence of selection. However, there are two main drawbacks. First, as with the instrumental variable approach, the identification of a suitable instrument is often a significant practical obstacle to successful implementation. Second, the resulting estimates are entirely contingent on the underlying distributional assumption relating to the unobserved variables.

2.1.5 Propensity Score Matching Model

More recently, the method of matching has achieved popularity as a tool of evaluation. It assumes that selection can be explained purely in terms of observable characteristics. Propensity score matching can be implemented with both cross-sectional and longitudinal datasets. Matching deals with the selection process by constructing a comparison group of individuals with observable characteristics similar to those treated. The main purpose of the matching is to re-establish the conditions of an experiment when no such data are available.

3. Cotton Marketing Results

3.1 Description of Variables

The data employed in the analysis were collected through a survey of 325 farmers from the seven highest cotton producing districts of the Punjab province[39]. The Punjab province was chosen for the survey because almost 80% of the cotton production in the country takes place in this province. A stratified random sampling technique was employed to select the farmers in the districts of Bahawalpur, Bahawalnagar, Vehari, Khanewal, Multan, Lodhran and Rahim Yar Khan. The districts were further divided into sub-districts and villages respectively for homogenous selection of data[40]. The sample ensured representation of farmers selling at the farm gate and travelling to the market. The survey was conducted through questionnaire interviews by local enumerators who

[39] In total, the Punjab province consists of 36 districts.
[40] Data was collected from 24 sub-districts and 115 villages.

were trained prior to the exercise, which took place between August and December 2007. The data collected included information on village infrastructure, households' background, socioeconomic characteristics of the farmer, land holding, cotton production, post harvest activities, sales, formal and informal credit sources and assets.

Table 1 presents definitions and descriptive statistics for the variables used in the empirical analysis. The survey indicated that 31% of the farmers sold cotton at the market and the rest sold at the farm gate. The most popular mode of transport used for cotton marketing was a tractor trolley (nearly 64% surveyed farmers have an own tractor) followed by mini trucks and animal carts, respectively. The majority of the farmers have access to road link in the village. The average distance to the market was 6.34 kilometres. The average age of farmers was almost 42 years, whereas the mean level of schooling was about 9 years. The farming experience was 23 years. About 65% of the farmers were working as owner of their land and the rest as tenants (both fixed renters and share croppers). The average land owned by the household was 31.3 acres and the cotton area per household was 31.76 acres. The average family size was 10 persons per household, whereas nearly 80% of the households were living in joint family systems and the rest 20% were living in nuclear family systems. Per acre cotton yield was about 905 kg per hectare. In comparison to the previous year's (2006-07) less cotton production, the cotton rate was high during the survey year (2007-08). About 43% of the farmers purchased inputs on credit from local traders (commission agent) due to high costs involved in cotton production. Most of the time these local traders (commission agent) interlock the supply of credit with the purchase of the cotton crop. Due to the intensive labour requirement, 83% of the farmers had hired labour (causal/ permanent) during the cotton season. The farm household's wealth was accounted as income earned by all the family members from farming and engagement in off-farm work plus the value of the current assets of the farmer like livestock ownership, etc. The district dummies are also included. All farm household heads interviewed were males[41]. The farmers were getting information about markets from personal visit, telephone, fellow farmers and the commission agent.

[41] So the gender role in marketing was not studied, as Cunningham et al. (2008) have focused.

Table 1: Definition of variables and descriptive statistics

Variable	Description	Sample Mean	Standard Deviation
Village Infrastructure			
Road access	1 if village has road access, 0 otherwise	0.83	0.37
Market distance	Distance to the nearest market in kilometres	6.34	6.75
Agri. extension	Distance to the Agri. extension office in kilometres	7.40	6.79
Characteristics of the farmer			
Age	Age of cotton farmer in number of years	42	12
Education	Number of years of schooling	9	4.3
Farming experience	Experience of farmer in number of years	22.6	13.5
Tenancy status	1 if farmer is owner of household, 0 otherwise	0.65	0.02
Land owned	Number of acres owned by the farmer	31.3	56.2
Operational land	Number of acres currently under cultivation	44.7	61.5
Cotton area	Number of acres under cotton cultivation	31.8	49.7
Male child	Number of male children in the household (< 16 years)	2.4	2.3
Female child	Number of female children in the household (< 16 years)	2.4	2.2
Adult male	Number of adult males in the household (16-60 years)	2.0	1.3
Adult female	Number of adult females in the household (16-60 years)	1.9	1.3
Old age male	Number of old age male in the household	0.4	0.5
Old age female	Number of old age female in the household	0.4	0.5
Household size	Number of people residing in the household	9.5	5.4
Family farm workers	Number of family members working at farm	1.9	0.9
Family type	1 if Joint family, 0 otherwise	0.8	0.4
Tractor	1 if household owns a tractor, 0 otherwise	0.6	0.5
Motorcycle	1 if household owns a motorcycle, 0 otherwise	0.8	0.4
Bicycle	1 if household owns a bicycle, 0 otherwise	0.7	0.5
Cotton yields	Cotton yield in kg/ha	905	0.2
Cotton rate	Cotton rate in Pakistani Rupees	1,532	88
Buy inputs on credit	1 if farmer buys inputs on credit, 0 otherwise	0.4	0.5
Membership	1 if farmer holds any organization membership, 0 otherwise	0.2	0.4
Extension contact	1 if farmer has contact with extension agent, 0 otherwise	0.8	0.4
Labour availability	1 if labour is available during cotton season, 0 otherwise	0.8	0.4
Market sale	1 if farmer sales at the market, 0 otherwise	0.3	0.5
Cotton Marketed	Amount of cotton sold at market in maunds	93.7	64.6
Non-farm work	1 if farmer is involved in non farm work, 0 otherwise	0.2	0.4
Household wealth	Total income from farm and non farm work in Rupees	46,415	3,037
Credit	1 if farmer has access to credit, 0 otherwise	0.34	0.02
Locations and Districts Dummies			
Bahawalpur	1 if the farmer is located in Bahawalpur district, 0 otherwise	0.17	0.4
Bahawalnagar	1 if the farmer is located in Bahawalnagar district,0 otherwise	0.10	0.29
Khanewal	1 if the farmer is located in Khanewal district, 0 otherwise	0.14	0.34
Vehari	1 if the farmer is located in Vehari district, 0 otherwise	0.16	0.36
Multan	1 if the farmer is located in Multan district, 0 otherwise	0.06	0.24
Lodhran	1 if the farmer is located in Lodhran district, 0 otherwise	0.18	0.39
Rahim Yar Khan	1 if the farmer is located in Rahim Y. K. district, 0 otherwise	0.19	0.39

Source: Survey data.

3.2 Empirical Results

3.2.1 Probit Results of Decision to Sell Cotton

The empirical analysis was conducted using the STATA statistical package. Due to the binary nature of the dependent variable, i.e. the market or the farm gate the Probit model (i.e. 1 for market selling and 0 for farm gate selling) was employed, and the results are presented in table 2. The model is expanded step by step by including more variables.

The McFadden R^2 as an indicator of the goodness of fit is 0.1683 and the likelihood ratio is 226.79 and significant at the 1%-level against a critical value of χ^2 (19) = 38.6. This suggests that the H_0 that all exogenous variables are 0 can be rejected and therefore the model implemented is reasonable and the results are robust.

The model started by including the market distance, tractor and district dummies. The result indicates that as the distance to the market increases the chances of selling cotton at the market decrease and vice versa. This result implies that mostly household situated close to the market sell at the market due to easy access and less transaction costs. With the increase in distance to the market, the proportionate transaction costs also increases and household prefer to sell cotton at the farm gate.

The household owning a tractor is more likely to sell at the market, as the coefficient is positive and significant at the 1% level of significance. This result indicates that household owning a tractor will prefer to sell at market and the household having no own transportation will most probably sell at farm gate, since a tractor is a significant mode of cotton transportation. The results of the asset ownership and the probability of selling at the market are in line with the findings of Boughton et al. (2007).

The model has been expanded by including the log of the quantity sold, the log of the household wealth, the log of the household size and the dependency ratio coefficients. The quantity sold results are positive and significant meaning that the larger the cotton quantity to be sold the higher chances of selling at the market. A large quantity of cotton is an indicator of wealthier household or large land holder farmers. This result implies that large farm having higher quantities of cotton mostly sell at market. The results of quantity sold at the market are in line with the findings of

Fafchamps and Hill (2005) in their study on coffee producers in Uganda. Similarly, the household's wealth coefficient is positive and significant, indicating that wealthier households have easy access to the markets compared to resource poor households. The household size and dependency ratio coefficient have a negative impact on selling at the market, although the coefficients are not significantly different from zero.

The model has been further expanded by including the interaction terms like log of distance and log of wealth interaction. The distance and wealth interaction coefficient has a positive impact on the household's decision of travelling to the market. This result implies that of two households with the same distance to the market, the one having more wealth is, more probable to market to sell cotton. Thus reconfirming the earlier results that wealthier households have easy access to the market. Similarly, the quantity and wealth interaction coefficient has a positive impact on selling at the market, meaning that of two households having the same quantity of cotton to sell the wealthier one is more likely to sell at the market and vice versa.

The credit taken from the local trader coefficient is negative and significant, implying that farmers who take credit from the local trader or commission agent mostly do not travel to the market for cotton selling but sell at the farm gate. The predicted values from the first stage estimates are also included in the model and the results are significant thus confirming the presence of endogeneity.

The model has been completed by including road access, household head's education and land tenure. The road access coefficient has a positive impact on the possibility of travelling to the market. This result focuses on the importance of improved infrastructure, although the coefficient is not significant, but it can be concluded that household having easy road access mostly sell cotton at the market and vice versa.

The household head's education coefficient is positive and significant at the 5% level of significance. In the model the household head education is included because the decision making mainly rests with the household head. The results clearly indicate that mostly the educated farmers sell cotton at the market and we can conclude from the results that farmers having lower levels of education sell at the farm gate. Regarding the districts fixed effects, most of the districts have a negative sign indicating that farmers mostly prefer to sell at the farm gate due to non availability of the market or having the market at a far off place.

Table 2: Probit results of decision to sell at the market

Variable	First	Second	Third	Fourth
Market distance	-0.325	-0.334	-0.257	-0.334
	(-1.36)	(-1.39)	(-0.88)	(-1.13)
Tractor (dummy)	0.474***	0.422**	0.427**	0.405**
	(2.85)	(2.22)	(2.10)	(1.98)
Log (quantity sold)		0.219*	0.277**	0.245**
		(1.69)	(2.28)	(2.16)
Log (household wealth)		0.469***	0.452*	0.404*
		(2.51)	(1.94)	(1.72)
Log (household size)		-0.579	-0.633*	-0.545
		(-1.54)	(-1.67)	(-1.39)
Dependency ratio[42]		-0.230	-0.284	-0.240
		(-1.34)	(-1.61)	(-1.35)
Log (distance)*log (wealth)			0.263***	0.287***
			(2.39)	(2.45)
Log (distance)*log (quantity)			0.693***	0.721***
			(2.65)	(2.69)
Log (quantity)*log (wealth)			0.007	0.002
			(0.16)	(0.05)
Credit taken from local trader				-0.326*
				(-1.71)
Rescredit				-0.028*
				(-1.89)
Road access (dummy)				0.293
				(1.26)
Household head education				0.034**
				(1.99)
Tenancy status (dummy)				0.166
				(0.83)
Bahawalpur	-0.512**	-0.539**	-0.579**	-0.530**
	(-2.05)	(-2.12)	(-2.22)	(-2.00)
Khanewal	-0.348	-0.493*	-0.566*	-0.540*
	(-1.27)	(-1.72)	(-1.94)	(-1.81)
Vehari	-0.612**	-0.618**	-0.699***	-0.637**
	(-2.34)	(-2.34)	(-2.60)	(-2.31)
Multan	-0.237*	-0.641*	-0.342*	-0.417*
	(-1.81)	(-1.77)	(-1.95)	(-1.68)
Lodhran	-1.509***	-1.649***	-1.780***	-1.655***
	(-4.80)	(-5.00)	(5.17)	(-4.74)
Rahim Yar Khan	-0.119	-0.140	-0.192	-0.143
	(-0.50)	(-0.57)	(-0.77)	(-0.56)
Constant	-0.285	-1.356	-0.681	-0.893
	(-1.41)	(-1.63)	(-0.68)	(-0.84)
Number of observation	325	325	325	325
McFadden R^2	0.1089	0.1336	0.1534	0.1683
Log Likelihood ratio	121.27	155.46	184.31	226.79

Note: The t-values are given in parentheses. The results are significantly different from zero at ***1%, **5% and *10% respectively.

[42] A household's dependency ratio is calculated by dividing the number of individuals under 16 years of age plus the number of individuals over 60 years of age by the total number of individuals in the household.

3.2.2 Instrumental Regression Results (Amount of Credit taken from Local Trader)

As discussed earlier, cotton is a high input demanding crop and especially pesticide, fertilizer and irrigation requirements are quite high. In order to meet the expensive input requirements, farmers mostly take credit (advance) from local traders or the commission agents. In return, the commission agents interlock the supply of credit with the purchase of cotton. Due to this endogeneity problem, the regression results have been instrumented for the amount of credit (advance) taken from the commission agent. As the amount of credit taken from the commission agent increases, the chances of selling at farm gate also increase. The total number of local traders (commission agents) visiting the farmers is used as an instrument. The instrument is strongly significant with F-statistics of 132.11. The R^2 of the instrumenting regression is 0.48, suggesting that it is unlikely to suffer from overfitting. The results are presented in table 3.

The results are positive for the distance to the market coefficient. The results indicate that households that are situated away from markets mostly take credit from the local trader and in return sell cotton to that particular person from whom they have taken the credit. From this finding it can be concluded that farmers living in far off villages having no market access mostly take higher amounts of credit as compared to farmers living close to the market.

The results are positive and significant for vehicle ownership, i.e. motorcycle in the study area. The vehicle ownership depicts the wealth status of the households. The result indicates that even to obtain credit from the informal source, the vehicle ownership play a positive and significant role as it can serve as a medium of guarantee.

The model has been expanded by including the log of household wealth, the results for which are positive and significant. The result implies that wealthy households obtain higher amounts of credit even from the informal sources in comparison with poor households.

The model has been further expanded by including road access, age and education coefficients. The results for road access are positive and significant, indicating that households having road access obtain a higher amount of credit from the local trader. The coefficient for the age of the farmer is positive and significant, indicating that older farmers are obtaining a higher amount of credit from the local trader compared to younger farmers. The result also implies that older farmers due to having more dealing, may have build the confidence with the local trader and in return are obtaining higher amounts of credit from the local trader. The result also implies that younger farmers mostly obtain less amount of credit from the local trader and hence prefer to sell at the market, while older farmers prefer to sell at the farm gate. The education coefficient is negative and significant, indicating that more educated farmers get a lower amount of credit from the local trader and hence prefer to sell at the market, while the less educated farmers get a higher amount of credit and in return sell to the local trader at the farm gate from whom they have taken the credit.

The model has been completed by including the household size and the dependency ratio. The household size coefficient is negative and significant, while the coefficient of the dependency ratio is positive and significant, thus indicating that household having more dependents in the household obtain a higher amount of credit from the local trader and in return prefer to sell at the farm gate instead of travelling to the market. Although the district dummies are not significant individually, districts fixed effects have been estimated as Abdulai and Hoffman (2005) have estimated and district fixed effects are different from zero though not significant.

Table 3: Instrumenting regression results for amount of credit taken from local trader

Variable	First	Second	Third	Fourth
Log (market distance)	0.111*	0.052	0.044	0.038
	(1.73)	(1.00)	(0.85)	(0.74)
Vehicle	0.552***	0.250***	0.220***	0.219***
	(6.93)	(3.67)	(3.20)	(3.19)
Log (wealth)		0.643***	0.640***	0.637***
		(13.19)	(13.06)	(12.87)
Road access			0.124*	0.110
			(1.78)	(1.58)
Age			0.005***	0.004**
			(2.38)	(2.13)
Education			-0.012*	-0.012*
			(-1.91)	(-1.93)
Household size				-0.014*
				(-1.63)
Dependency ratio				0.190**
				(2.31)
Bahawalpur	0.034	-0.050	-0.017	-0.018
	(0.30)	(-0.55)	(-0.20)	(-0.21)
Khanewal	0.280**	-0.031	-0.022	-0.025
	(2.33)	(-0.32)	(-0.23)	(-0.25)
Vehari	0.193*	0.121	0.175*	0.150
	(1.70)	(1.32)	(1.91)	(1.63)
Multan	0.033	0.045	0.012	0.055
	(1.21)	(1.27)	(1.45)	(1.61)
Lodhran	0.515***	0.117	0.166*	0.159*
	(4.57)	(1.24)	(1.75)	(1.68)
Rahim Yar Khan	0.061	-0.025	-0.001	-0.010
	(0.57)	(-0.29)	(-0.01)	(-0.11)
Constant	2.152***	-1.368***	-1.793***	-1.684***
	(19.36)	(-4.86)	(-5.76)	(-5.36)
Number of observations	325	325	325	325
Adjusted R^2	0.1732	0.4658	0.4805	0.4849
F-test on significance of Instruments	132.11***	109.75***	94.68***	63.27***

Note: The t-values are given in parentheses. The results are significantly different from zero at ***1%, **5% and *10%, respectively.

3.2.3 Heckman Selection Estimator for Quantity of Cotton Sold

The results of the Heckman selection estimator for the quantity sold at the market are presented in table 4. The Heckman model is employed for the quantity of cotton sold at the market to account for selectivity bias. The value of lambda (λ) is positive and highly significant, indicating that selection effects are significant. The Wald test statistics is 135.86 and is significant at the 1% -level of significance against a critical value of χ^2 (16) = 34.3, indicating that model results are robust.

The result for the road access coefficient is positive, though not significant. This indicates that households having road access sell higher quantities of cotton at the market. This emphasises the importance of infrastructure not only for having easy access to the markets but also the volume transacted at the markets.

The tractor ownership coefficient is positive and highly significant at the 1% level of significance, indicating that households owning a tractor sell higher quantities of cotton at the market. In contrast the farmers having no own tractor prefer to sell at the farm gate. As tractor ownership is also an indicator of household wealth, it can be concluded that wealthy households sell higher quantities of cotton at the market.

The age coefficient is negative and significant, indicating that young farmers sell higher quantities of cotton at the market, while the old age farmers sell lower quantities of cotton in the market. The education coefficient is positive and highly significant, indicating that educated farmers sell higher quantities of cotton at the market, while the farmers having less levels of education sell less quantities of cotton at the market. The results for the tenancy status are positive, though not significant, indicating that owners mostly sell larger volumes of cotton in the market, while the tenants sell less quantities of cotton in the market.

The log of the household wealth coefficient is positive and highly significant, indicating that wealthy households sell higher quantities of cotton at the market. Since wealthier households have easy access to the markets due to having own transport they sell large volumes of cotton in the market, while poorer households sell less volumes of cotton in the market. The log of the distance to the market coefficient is negative, indicating that as the distance to the market increases, farmers prefer to sell less amount of cotton in the market due to higher proportional transaction costs and more labour requirement. As a consequence, the farmers located in the far off areas mostly prefer to sell at the farm gate instead of travelling to the market. The log of wealth and the log of distance coefficients are negative meaning that comparing two households with the same wealth the one who has to travel a longer distance will probably sell less quantities of cotton at the market.

The land ownership coefficient is positive and highly significant. As land ownership is also an indicator of household wealth, the result indicates that farmers having higher land ownership or the wealthy households sell higher quantities of cotton at the market, while the small farmers having less or no land holding sell less quantities of cotton at the market. The coefficient of labour availability is also positive and highly significant, indicating that households having more labour availability sell higher quantities of cotton at the market, since during cotton marketing the labour is needed for loading, unloading and transportation of cotton at the market.

Table 4: OLS regression (Heckman) results for quantity of cotton sold at market

Variable	Coefficient	z-value
Road access	0.320	1.32
Tractor (dummy)	0.592***	2.50
Age	-0.020**	-2.16
Education	0.067***	3.01
Tenancy status	0.487	1.23
Log (household wealth)	0.750***	2.38
Log (wealth)*log(distance)	-0.298	-0.57
Household size (number)	0.058**	2.05
Land owned	0.057***	3.70
Labour availability	0.983***	3.72
Bahawalpur	0.082	0.19
Bahawalnagar	0.653*	1.66
Khanewal	0.115	0.24
Vehari	0.03	0.06
Lodhran	0.109	0.24
Rahim Yar Khan	0.526	1.21
Constant	2.59*	1.69
λ	0.446***	2.60
Rho	0.735	
Number of observations	325	
Censored Observations	45	
Uncensored Observations	280	
Wald χ^2	135.86	
Prob> χ^2	0.000	

Note: The results are significantly different from zero at ***1%, **5% and *10%, respectively.

3.2.4 Tobit and CLAD Model Results for Distance Travelled to Sell Cotton

Both CLAD and Tobit models are employed to estimate the distance travelled to sell cotton. The censored least absolute deviation (CLAD) model has been estimated[43]. Since in the face of heteroskedaticity or non-normality, the Tobit model produces biased estimates. In contrast, since the censored least absolute deviation (CLAD) estimator does not depend on distributional or homoskedasticity assumptions of the errors and is robust to censoring, it produces consistent estimates even in the face of heteroskedasticity, non-normality and censoring. As the CLAD estimator imposes the weakest stochastic restrictions on the error terms, it results in the most precise estimates of the policy effects[44].

The results of the CLAD and Tobit models for distance travelled to sell cotton are presented in table 5. The result for the road access coefficient is positive and significant, indicating that household having road access can travel longer distances to sell cotton or in other words having a road access is the pre-requisite for market participation. In the study area, few villages have no road access at all and hence the farmers prefer to sell at the farm gate to the local trader instead of travelling to the market. Hence, good infrastructure can enhance farmers' chances of selling at the market.

The tractor ownership coefficient is positive and significant, indicating that households owning a tractor can travel longer distances to sell cotton at the far off markets. The age coefficient is negative though not significant, indicating that young farmers can travel long distance to sell cotton at the market. The land ownership coefficient is positive and significant, indicating that households having more land ownership can travel longer distances to sell cotton. As land ownership is also an indicator of household's wealth since the results indicate that wealthy households can access the far off markets for cotton selling.

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[43] The CLAD estimator is a generalization of the least absolute deviation (LAD) estimator. Unlike the standard estimators of the censored regression model such as Tobit or other maximum likelihood approaches, the CLAD estimator is robust to heteroskedasticity and is consistent and asymptotically normal for a wide class of error distribution.

[44] The censored least absolute deviation (CLAD) estimator for the censored regression model has been regarded as a desirable alternative to maximum likelihood estimation methods due to its robustness to conditional heteroscadesticity and distributional misspecification of the error term. However, the CLAD procedure has failed in certain empirical applications due to the restrictive nature of the "full rank" condition it requires. This condition can be especially problematic when the data are heavily censored.

The tenancy status results are positive, indicating that owners travel longer distances to sell cotton while the tenants mostly sell at the farm gate. Since the owners have higher land holding and more assets compared to tenants, they can travel longer distance to access cotton markets at the far off place. The tenants with fewer resources need credit from the local trader to meet the expensive input requirements and in return prefer to sell at the farm gate.

The results of the residuals of the quantity are not significant (the first stage estimates of quantity sold are presented in Appendix A-1). The result of the household size coefficient is also not significant. The log of quantity and log of wealth interaction is positive and significant, indicating that for the same quantity wealthier households can travel longer distances to sell cotton. The districts dummies are also included in the model.

Table 5: Tobit and CLAD results for distance travelled to sell cotton

Variable	CLAD		Tobit	
	Coefficient	t-values	Coefficient	t-values
Road access	0.957**	2.09	0.878*	1.93
Tractor (dummy)	1.818*	1.95	1.565*	1.72
Age	-0.033	-1.43	-0.564	-1.16
Education	0.033	0.97	0.732	1.56
Land owned	0.007*	1.75	0.031***	2.50
Tenancy status	1.817*	1.66	0.986*	1.82
Log (wealth)	0.401	1.48	0.001*	1.66
Residuals of quantity sold	0.002	1.14	0.005	1.33
Household size	0.024	0.89	0.03	0.57
Log (quantity)* Log (wealth)	0.296**	2.19	0.405***	2.83
Bahawalpur	2.413*	1.83	1.180	1.20
Bahawalnagar	4.330***	2.45	0.194	0.16
Khanewal	-0.216***	2.88	-0.348	-0.31
Multan	0.173***	2.306	2.01	1.42
Lodhran	-1.201	0.51	-0.185*	-1.82
Rahim Yar Khan	2.698*	1.92	2.101**	2.00
Constant	3.386***	2.864	3.452**	2.06
Sigma (σ)			5.051	
LR χ^2			277.51	
Prob > χ^2			0.000	
Initial sample size	325		325	
Final sample size	223		325	
Pseudo R^2	0.4105		0.1825	

Note: In CLAD bootstrap replications are 100. The results are significantly different from zero at ***1%, **5% and *10%, respectively.

3.2.5 Propensity Score Matching Results for Net Returns

Propensity score matching estimates for cotton net returns are presented in table 6. Different matching algorithms like nearest neighbour matching (NNM), kernel based matching (KBM), radius matching and mahalnobis metric matching (MMM) with different calipers and bandwidths are employed to carry out the analysis of cotton net returns to selling at the market or the farm gate. The farmers selling at the market get higher net returns in the range of Rupees 1,875-5,434, thus indicating that cotton farmers who have access to markets get higher net returns compared to farmers selling at the farm gate. Similar results were obtained by Smith et al. (1999). Since they found that farmers who interlock the credit from informal sources to the supply of output received lower cotton prices compared to the farmers who had not interlocked the cotton output with the provision of credit from the local traders. In other words, farmers having independent choice regarding the place of sale, get higher prices compared to farmers who do not have independent choice regarding the place of sale. The results of higher returns from cotton when the farmers sell at the market are also in line with Boughton et al. (2007), since they observe higher returns for cotton selling at the market in Mozambique.

Critical levels of hidden bias are presented in the third column of table 6. The critical level of hidden bias of e.g. 1.20-1.25 indicates that farmers selling at the market and selling at the farm gate differ due to unobservable factors by 20-25%. The results are sensitive to very low as well as to very high values of the hidden bias. In the present analysis the value of hidden bias varies between 1.10-1.95. It can therefore be concluded that results are robust and not sensitive to hidden bias. This unobserved heterogeneity indicates that there are some unobserved variables simultaneously influencing the participation decision and the outcome. However, it has to be stressed that the Rosenbaum bounds are a worst-case scenario since they do not question the significance of the causal effects, but they show the required extent of a confounding variable on the market participation probability to undermine the significance of the average treatment effects.

Since the main purpose of the propensity score matching is to balance the covariates among participants and control groups, table 7 presents the indicators of covariates balancing after propensity score matching. A number of different balancing tests have been performed. The results indicate that after matching, the median absolute bias has been reduced considerably and is low after matching in all the matching algorithms.

Before matching the median absolute bias lies in the range of 17% and 21%, and after matching the median absolute bias lies in the range of 5% to 11%. Rosenbaum and Rubin (1985) suggested that a remaining standardised bias of 20% is quite acceptable. In all the matching algorithms, the bias has considerably decreased after matching, e.g. in the range of 45% - 72%. The results indicate that after matching, the bias has been decreased by a considerable amount and the covariates have been balanced and hence, the results are robust.

Similarly, the value of the pseudo-R^2 is really low after matching depicting that there are no systematic differences between adopters and non adopters after matching. The last two columns in table 7 indicate the joint significance of covariates. Before matching, the null hypothesis of equal covariate means for both groups of households should be rejected and after matching, the *p*-value of the likelihood ratio test should be quite high so that the hypothesis of statistically similar samples cannot be rejected anymore.

Table 6: Average treatment effects and results of sensitivity analysis for net returns

Matching Algorithm	Caliper/Bandwidth	ATT	Critical level of hidden Bias	Number of Treated	Number of Control
Nearest Neighbour Matching(1)	0.01	2264.98* (1.77)	1.20-1.25	96	192
Nearest Neighbour Matching(2)	0.05	3919.47*(1.86)	1.55-1.60	96	192
Nearest Neighbour Matching(5)	0.9	4345.19**(2.18)	1.45-1.50	96	192
Nearest Neighbour Matching(10)	0.05	2945.76*(1.71)	1.75-1.80	96	192
Kernel Based Matching	0.5	3242.20*(1.66)	1.55-1.60	96	192
Kernel Based Matching	0.9	4550.02***(2.54)	1.40-1.45	96	192
Kernel Based Matching	0.01	1875.13**(2.19)	1.35-1.40	96	192
Kernel Based Matching	0.05	3748.44*(1.80)	1.90-1.95	96	192
Radius Matching	0.5	4556.68**(1.98)	1.25-1.30	96	192
Radius Matching	0.9	4665.38***(2.65)	1.35-1.40	96	192
Radius Matching	0.05	3957.74*(1.83)	1.55-1.60	96	192
Radius Matching	0.01	4555.86* (1.77)	1.45-1.50	96	192
Mahalanobis Metric Matching	0.01	3483.21**(2.11)	1.10-1.15	82	61
Mahalanobis Metric Matching	0.02	4163.21*(1.90)	1.25-1.30	40	37
Mahalanobis Metric Matching	0.03	5011.63*(1.88)	1.45-1.50	49	45
Mahalanobis Metric Matching	0.05	5434.61 (1.59)	-	55	49

Note: t-values are reported in parentheses and the values are significantly different from zero at the ***1, **5 and *10% level, respectively. For Kernel based matching, the bandwidths are reported and for nearest neighbour matching, radius matching and mahalanobis metric matching, the calipers are reported.

Table 7: Indicators of covariate balancing before and after matching

Matching Algorithm	Caliper	Median absolute bias (before matching) %	Median absolute bias (after matching) %	(Total)% bias reduction	Pseudo R^2 (unmatched)	Pseudo R^2 (matched)	$P > \chi^2$ (unmatched)	$P > \chi^2$ (matched)
Nearest Neighbour Matching(1)	0.01	21.51	6.00	72.10	0.244	0.034	0.000	0.764
Nearest Neighbour Matching(2)	0.05	20.22	7.26	64.09	0.259	0.014	0.000	0.587
Nearest Neighbour Matching(5)	0.9	20.79	7.70	62.96	0.261	0.006	0.000	0.945
Nearest Neighbour Matching(10)	0.05	20.51	6.57	67.96	0.282	0.002	0.000	0.987
Kernel Based Matching	0.5	19.75	9.49	51.94	0.266	0.001	0.000	0.632
Kernel Based Matching	0.9	18.65	9.21	50.62	0.258	0.002	0.000	0.534
Kernel Based Matching	0.01	18.44	7.26	60.63	0.295	0.012	0.000	0.997
Kernel Based Matching	0.05	17.67	6.33	64.17	0.334	0.022	0.000	0.841
Radius Matching	0.5	20.51	11.16	45.59	0.281	0.026	0.000	0.999
Radius Matching	0.9	20.27	8.41	58.51	0.279	0.058	0.000	0.961
Radius Matching	0.05	20.57	7.93	61.49	0.284	0.049	0.000	0.925
Radius Matching	0.01	20.11	6.69	66.73	0.277	0.099	0.000	0.475
Mahalanobis Metric Matching	0.01	20.66	7.35	64.42	0.268	0.074	0.000	0.273
Mahalanobis Metric Matching	0.02	19.63	5.68	71.06	0.279	0.001	0.000	0.808
Mahalanobis Metric Matching	0.03	19.64	11.52	58.66	0.241	0.022	0.000	0.780
Mahalanobis Metric Matching	0.05	20.33	6.79	66.60	0.246	0.033	0.000	0.509

6. Conclusions

The results indicate that cotton farmers' market participation is not driven by the self control motive but there are a number of factors influencing the farmers' market participation. The empirical results from the analysis show that road access, transport availability, the household's wealth and the household head's education contribute positively and significantly to the sale of cotton at the market.

The most important finding is the positive and significant difference in net returns farmers receive at the market or at the farm gate. The difference in net returns indicates that farmers selling at the market are gaining higher net returns compared to farmers selling at the farm gate. But it can be clearly concluded from the results that wealthy households have easy access to markets. On the contrary, small and resource poor farmers are getting less returns by selling at the farm gate to local traders (commission agent). The results also indicate that wealthy households can travel longer distances and can sell higher quantities of cotton in the market. Small farmers have fewer resources and need to take credit from the informal source, i.e. local trader (commission agent). Hence, they are bound to sell to the local commission agent. In this situation, the formal credit programme needs to be transparent, quick and easy for landless and small farmers. However, the formal credit programme is currently not small farmers friendly, since the procedure is long, not transparent and mark up rates are quite high. The landless farmers have no access to the formal credit programme at all and as a consequence, the small and landless farmers turn to informal credit sources and in return sell cotton to them on the offered rates. The results emphasise the improvement in infrastructure and the establishment of markets at districts level. The government should invest in human capital development and information about market prices should be provided to farmers through print and electronic media.

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Appendix

Table A-1 First stage estimates of determinants of quantity sold

Variable	Coefficient	t-values
Road Access	341.83*	1.94
Age	-0.268	-0.05
Education	22.372	1.31
Tenancy	266.43	1.13
Land owned	15.55***	10.98
Tractor	146.98	0.86
Labour	140.88	0.72
Log (wealth)	301.97*	1.86
Bahawalpur	486.27	1.59
Bahawalnagar	319.89*	1.84
Khanewal	473.36	1.51
Vehari	509.21*	1.66
Lodhran	795.01***	2.58
Rahim Yar Kahn	141.72	0.47
Constant	10798.06***	3.95
Number of Observation	325	
F(22, 302)	28.84	
Prob>F	0.000	
R^2	0.6775	
Adjusted R^2	0.6541	

Note: The results are significantly different from zero at ***1%, **5% and *10%, respectively.

Chapter 6

Conclusions and Implications

The analysis conducted in this dissertation is focusing on three important aspects of production and marketing of cotton in Pakistan. First, the adoption and impact of Bt cotton technology on cotton yield, household income, poverty status of the household and pesticide demand; second, the land rights' influence on farmers decision to invest in land improvement measures and impact on technical, allocative and economic efficiency levels of cotton farmers; third, the impact of transaction costs and liquidity constraints on cotton farmers' market participation. The major motivation for the study was that genetically modified cotton varieties are recently introduced in Pakistan and this is the first study which has estimated the adoption and impact of Bt cotton by employing the propensity score matching approach. The main advantage of the new technology are the higher yields and incomes and less pesticide demand besides poverty reduction as well as socioeconomic benefits to the household.

1. Study Focus and Review of Methods

The present study is the first Bt cotton adoption and impact assessment study in Pakistan. The study employed the propensity score matching (PSM) approach to reduce potential issues of non random sample selection. This approach is quite new in the growing literature on the impact of genetically modified crops. In the past, Bt cotton studies in developing countries has mainly focused on cotton yields and pesticide use, but the household poverty aspect was mostly missing in the past literature. In the present study Bt cotton impacts on cotton yields, household income, pesticide demand and poverty status are estimated. The second important focus of this dissertation is on land rights' influence on farmers' decision to invest in land improvement measures and efficiency level. The third important focus is on the role of transaction costs and liquidity constraint on cotton farmers' market participation. Only a couple of studies in Pakistan have studied the land rights' influence on farmers' decision to invest in land improvement measures, but no study has related this to farmer's technical, allocative and economic efficiency levels. A multivariate Tobit model is employed to estimate farmers' investment in land improvement measures and translog profit and cost frontier models are employed to estimate the technical, allocative and economic efficiency levels. The propensity score matching approach was also employed to assess the impact of investment in soil improving and fertility enhancing measures. The study also focused on cotton farmers' market participation. So far, only little literature exists on farmers' market participation and determinants of participation. In the present study, a number of different models are employed to estimate the farmer's market participation. A Probit model is employed for farmers' market participation and results are instrumented for the amount of advance taken from the commission agent and the Heckman selection estimator is employed for the quantity of cotton sold. Both CLAD and Tobit models are employed for the distance travelled to sell cotton and the propensity score matching approach is employed for cotton net returns.

2. Summary of Results and Implications for Policy

2.1 Genetically Modified Cotton Impact on Household Welfare

The adoption of genetically modified cotton is helpful in increasing cotton yields and household income. These benefits usually manifest themselves in the form of poverty reduction. The empirical results from the analysis show that the adoption of the Bt cotton has a positive and significant impact on cotton yields, household income and poverty reduction, and a negative impact on pesticides demand. For example, the estimates reveal that cotton yields are by 50-62 kg per acre higher for farmers who adopted Bt cotton technology. This can be considered as the opportunity cost of not adopting the Bt cotton varieties. Similarly, the household incomes are higher by Rupees 16,500-17,000 pesticide demand was less by 0.62-0.68 liters per acre and Bt cotton is helpful in reducing the household poverty by 13.5-14.3%. The positive and significant impact of the technology on cotton yields and household income reaffirms the potential role of new agricultural technology in directly reducing the rural poverty through increased farm household incomes. The negative and significant impact of the technology on the demand for pesticide shows that as an inbuilt pest resistance mechanism, Bt cotton could result in substantial ecological benefits. The reduced demand for pesticide is encouraging not only for ecological reasons, but also for health reasons, as they are potentially harmful for human health, particularly under the conditions of usage in several developing countries.

The estimates differentiated by land ownership indicate that the productivity gains from Bt cotton are higher for small scale farmers compared to medium and large scale farmers. The income effect of technology appears to be higher for large farmers.

However, adoption tends to help small farmers out of poverty but exerts no statistically significant impact on medium and large farmers' poverty status. The policy implications of this finding is that targeting small-scale farmers with new agricultural technology can help in improving their farm productivity, income and reduce poverty among these households. Policies in this direction include increasing their access to information to reduce uncertainty about new technologies and to formal credit to overcome liquidity constraints. In addition, efforts to improve their human capital in the form of education and providing them with better infrastructure as well as advanced extension services would go long way to help facilitating the adoption of new technologies.

2.2 Land Rights Influence on Farmers' Decision to Invest in Land Improvement Measures and Efficiency Levels

Robust evidence was found that secured land rights do matter when farmers make investment decisions about soil improving measures such as organic manure and cultivation of leguminous crops and mineral fertilizers. Specifically, farmers with secured land rights were found to be more likely to invest in soil improving measures compared to tenants. However, tenure security did not matter for investments in short-term yield enhancing inputs such as mineral fertiliser, since fixed-rent tenants were found to apply higher levels than owner-cultivators. While both moral hazard and hold-up problems may explain the lower levels of investment by sharecroppers, the finding for fixed-renters may be attributed to landlords who do not fully commit to their contracts with fixed-renters. Under such conditions, fixed-renters do not find it attractive to invest in long-term soil improving measures since the landlord could deny to extend the contract once it expires, preventing the tenant from reaping the benefits of the investment.

We also find empirical support for the hypothesis that farmers with secured land rights are more efficient than those with leased contracts. Specifically, the average alloctaive efficiencies for owner-cultivators, sharecroppers, and fixed-renters are 92%, 82%, and 85% respectively. Although these average efficiency differences between owner-cultivators and those of tenants do not appear to be large, the averages actually concede great heterogeneity across tenure arrangement types. The higher levels of efficiency on owner-cultivator farms stem from the higher incentives to invest in soil-improving and productivity enhancing measures, and to exert great effort in production. Given the high cost of supervision in Pakistan, landlords rarely supervise their share-tenants, resulting in tenants exerting less effort and therefore achieving lower productivity levels. These findings generally suggest that a land redistribution exercise in favour of sharecroppers and fixed-renters could have considerable efficiency effects.

A propensity score matching model was also employed to assess the impacts of investments in soil improving and productivity-enhancing measures on farm productivity and efficiency. The findings revealed that investment in organic manure, fertilizer and leguminous crops exert positive impacts on farm productivity and efficiency, suggesting that investment in these soil improving and yield enhancing measures may partially account for the productivity and efficiency impacts of tenure security. Overall, our results indicate that redistribution of land that strengthens tenure security can have substantial investment and efficiency effects in agricultural production.

2.3 Determinants of Cotton Marketing

The results depict that the cotton farmers' market participation decision is influenced by a number of factors. The empirical results shows that road access, transport availability, the household's wealth and the household head's education have a positive and significant influence on the cotton farmers' market participation.

There is a positive and significant difference in cotton net returns farmers receive at the market and at the farm gate. Propensity score matching results indicate that farmers having access to the market are getting more net returns compared to the farmers selling at the farm gate. This can be clearly concluded from the results that wealthy household have easy access to markets. Small farmers have fewer resources and they take credit from the informal source, i.e. local trader (commission agent), hence they are bound to sell to the local trader (commission agent) at the farm gate. The formal credit programme needs to be transparent, quick and easy for small scale farmers and tenants. But currently, the formal credit programme is not small farmers friendly since the procedure is long, non-transparent and mark up rates are quite high. The landless farmers have no access to formal credit programme at all. So the small and landless farmers turn to informal credit sources and in return interlock output supply to them. The results emphasise the improvement in infrastructure, the establishment of markets at district levels and the investment in human capital development.

3. Policy Implications

The present study has a number of important policy implications. As far as the household's welfare is concerned, the Bt cotton has a positive and significant impact on cotton farmers in Pakistan. Policy makers should ensure the supply of healthy Bt cotton seed to farmers. The land rights' influence on farmers' decision to invest in land improvement measures indicate that farmers having secure land rights invest more in land improvement measures and vice versa. As owners are technically, allocativelly and economically more efficient, tenants should be provided with land rights through land reforms since this will be added incentive for the landless and resource poor farmers to invest in land improvement measures and hence higher levels of technical, allocative and economic efficiency levels can be achieved. The gap between highest and lowest efficiency levels indicates the scope for improvement.

The policy implications for farmers' market participation are that the formal credit programme needs to be made more transparent, easy and quick for the small scale farmers. Besides this, the improvement in village infrastructure and the investment in human capital is also needed.

4. Directions for Future Research

Since the current study was the first study regarding the adoption and impact of Bt cotton, more studies regarding Bt cotton adoption and impact evaluation should be carried out in the future to have a clear understanding how the new technology has performed over the years regarding household welfare. Future researchers can also focus on other areas of Bt cotton adoption and impact evaluation like impact on the farmers' health status.

Due to time and resource constraints, only cross-sectional data were collected for the present study, so future researchers can possibly employ panel data to estimate the land rights' influence on farmers' decision to invest in land improvement measures and efficiency level. Especially for efficiency estimation, cross sectional data provide only a snapshot for efficiency estimation, while panel data provide a comprehensive overview. Therefore, future researchers in Pakistan should focus on this issue.

Regarding cotton farmers' access to the markets, the main focus was on the farmers' decision to sell at the market and determinants of the farmers' market participation and household net returns. Hence, future studies can be expanded to other market stakeholders involved in the cotton marketing chain. Last but not least similar studies for cotton and other crops in the developing countries can be helpful regarding policy formulations and rural household welfare.

Appendix A
OPPORTUNITIES AND CONSTRAINTS IN PRODUCTION AND MARKETING OF COTTON IN PAKISTAN

Questionnaire Nr_________________

Name of Enumerator _________________________________

Date of Interview [____ /____ /_____](DD/MM/YY)

Time started ________________ Time ended_________________

Signature_______________________________

Reviewed by _________________________________

Date [____ /____ /_____](DD/MM/YY)

Signature of Reviewer ____

Instructions

- Please explain to the farmers the purpose of getting information.
- Please interview only 1 farmer from one household (e.g., if father and son are also involved in farming for the same piece of land then interview only one person).
- Please try to complete as accurately as possible.
- Please use codes where provided.
- Please specify units clearly whenever you write quantity and prices.
- About sensitive questions like income and family please ask these questions at the end.
- Please make sure that no important column is missing, so after completing and before saying good bye to farmer check once again.

A / Village Information

Please write down the name of district, tehsil and village of the respondent.

A / 1 District [____]

A / 2 Tehsil [____]

A / 3 Village/ Place [____________________________________]

A / 4 Infrastructure in the village

Please make a cross [x] in the relevant box if the facility is available then in front of yes and if not then in front of no. If the facility is not available then please mention the approximate distance at which the facility is available.

Facility	Yes	No	Distance (Kms)	Facility	Yes	No	Distance (Kms)
Mettle Road	[__]	[___]	[___]	Primary School girls	[____]	[____]	[____]
Brick Road / Soling	[___]	[___]	[___]	Hospital	[____]	[____]	[____]
Transport	[___]	[___]	[___]	Veterinary Centre	[____]	[____]	[____]
Electricity	[___]	[___]	/////////////	Agriculture NGO,s	[____]	[____]	[____]
Inputs Dealer	[___]	[___]	[___]	Agri. Extension office	[____]	[____]	[____]
Crops Output Market	[___]	[___]	[___]	Agri. Research Institute	[____]	[____]	[____]
Primary School boys	[___]	[___]	[___]	Agri. Bank	[____]	[____]	[____]

B/ Personal Information

B/1 Name of Farmer [____]

B/2 Age (Years) [_________________] **B/3** Education (Years) [______________]

B/4 Farming Experience (Years) [___] **B/5** Cotton Growing Experience (Years) [__]

B/6 Gender of Household Head [________________________] 1. Male 2. Female

B/7 Relationship of the farmer with household head [_________________________]

B/8 Status of the Farmer [___________] 1. Owner 2. Tenant 3.Owner cum Tenant

B/9 Land owned by the farmer (acres) [_____________________]

B / 10 Land owned by the father (acres) [_____________________]

B/11 Farm Land Resources (Number of acres)

Total Own Land		Area Rented In	Area Rented Out	Area Shared In	Area Shared Out	Operational holding
Cultivated	Un-Cultivated					
[_____]	[_____]	[_______]	[_______]	[___]	[__]	[______]

Land rent if rented in or rented out (6months / cotton season) [__________________]

Owner share percentage if shared in or shared out (6months / cotton season) [_____]

B/12 Crops and Area Information (Acres)

Please provide information about different crops sown during summer and winter season

Crops (Kharif)	Area (acres)	Vegetables (Kharif)	Area (acres)	Crops (Rabi)	Area (acres)	Vegetables (Rabi)	Area (acres)
[**Cotton**]	[___]	[_______]	[___]	[_____]	[___]	[_______]	[___]
[_______]	[___]	[_______]	[___]	[_____]	[___]	[_______]	[___]
[_______]	[___]	[_______]	[___]	[_____]	[___]	[_______]	[___]

B/13 Total area of cotton planted during the last season (number of acres) [________]

B/14 Have you kept some part of your land fallow [_______________] 1. Yes 2. No

B/15 If yes then please give number of acres left fallow [__________________]

B/16 What is the over all type of your soil? Please choose from the below choices. [_]
1. Clay 2. Loam 3. Clay Loam 4.Sandy Loam 5. Silt loam 6. Others [___________]

B/17 Main soil type at which cotton is planted [________]1. Good 2. Medium 3. Poor

B/18 Have you ever carried out soil test? [____________] 1. Yes 2. No

B/19 Do you have idea / information about micro nutrients?[_________] 1. Yes 2. No

B/ 20 Has over the years soil fertility decreased? [_________] 1. Yes 2. No

B/21 Is the fertility levels same in all the plots? [_________] 1. Yes 2. No

B/22 Have you planted fertility enhancing crops like legumes [_________] 1. Yes 2. No

B/23 Number of cotton plots [_____] 1. One 2. Two 3. Three 4.Four 5.Other [____]

B/24 If fragmented then distance between two farthest cotton plots in kms [________]
Or distance of the farthest plot from farmer's home in kms [______________]

B/25 Family Information

Household Size and Education level

Please fill the following information regarding size of family members.

Children (Less than 16 years)		Adult (16-60)		Old age (above 60)		Male Family Farm Workers	Female family farm workers
Male	Female	Male	Female	Male	Female		
[__]	[____]	[___]	[____]	[___]	[___]	[_______]	[________]

B-26 Highest Education in the family (years of education) [_____________________]

B-27 Education level of Family household head [____________________________]

B-28 Family Type [__________________________]1. Joint Family 2.Nuclear Family

B-29 Assets of Farmers

Please Cross[x] in front of the relevant column, if the farmers have that particular assets or not. Please also mention the total number if the answer is yes.

Assets	Yes	No	Number	Assets	Yes	No	Number
Tube wells	[___]	[___]	[____]	Fodder Cutter	[___]	[___]	[____]
Wells	[___]	[___]	[____]	Manual Spray Machine	[___]	[___]	[____]
Plough	[___]	[___]	[____]	Tractor driven spray machine	[___]	[___]	[____]
MB Plough	[___]	[___]	[____]	Laser Leveler	[___]	[___]	[____]
Chisel plough	[___]	[___]	[____]	Radio	[___]	[___]	[____]
Tractor	[___]	[___]	[____]	Television	[___]	[___]	[____]
Trolley	[___]	[___]	[____]	Car / Vehicle	[___]	[___]	[____]
Thresher	[___]	[___]	[____]	Motorcycle/Scooter	[___]	[___]	[____]
Rotavator	[___]	[___]	[____]	Bicycle	[___]	[___]	[____]
Rabi drill	[___]	[___]	[____]	Milk Animals cow / Buffalo	[___]	[___]	[____]
Zero-till drill	[___]	[___]	[____]	Bullock	[___]	[___]	[____]
Hand cotton drill	[___]	[___]	[____]	Sheep & Goats	[___]	[___]	[____]
Tractor driven cotton drill	[___]	[___]	[____]	Camel / Horses / Donkeys	[___]	[___]	[____]
Electric Motor	[___]	[___]	[____]	Hens	[___]	[___]	[____]

Cotton Production Practices

C/ Land Preparation; Mode of preparation

C/1 Which tools do you use for land preparation; please enter code from the choices [________] or cross[x] in front of choice

1. Own Bullock	
2.Own Tractor	
3. Hired Bullock	
4. Hired Tractor	
5. Both Bullock and Tractor	

C/2 Is the tractor for land preparation easily available [_____] 1. Yes 2. No

C/3 Total land prepared / ploughed in acres for cotton during 2006-07 season [___]

C/4 Total Number of Ploughing / acre [________], Cost in Rupees [_____________]

C/5 Total Number of Planking / acre [________], Cost in Rupees [_____________]

C/6 What do you pay for total land preparation in Rupees [______________________]

C/7 Cost of per acre land preparation [_____________________________________]

C/8 Month / Date of cotton sowing (exact date / month) [______________________]

C/9 Seed Sources

What is your source of cotton seed, please fill from the given choices [___] [___]
Or cross[x] in front of choice

1.Own	
2.Fellow Farmers	
2. Market Dealer / Seed Agency	
3. Govt. Offices	
4. Others	

C/10 Quantity of cotton seed used per acre in Kilograms [____], Price per kilogram[_]

C/11 Price of seed, if own seed used then total approximate market value in Rupees [__________]

C/12 Seed Treatment

Please provide information about seed treatment from the below choices [_____] or cross in front of choice

1. Already Treated	
2. Treated by himself	
3. Not Treated	

C/13 If himself carried out seed treatment then name of chemical used [___________]

C/14 Quantity of chemical used for treating 40kg of seed in liters [_______________]

C/15 What is total cost of chemical [_________________________________]

C/16 What is per acre cost of chemical [_///////////////_______________]

C/17 Pre sowing irrigation (rauni) [___________________] 1. Yes 2. No

C/18 If yes then number of irrigation (Raunis) [_________] 1. Single 2. Double

C/19 Approximate cost of raunis [_____________________________________]

C/20 Sowing Method

What sowing method did you used for cotton crop land preparation, please enter from the following choices [_______________]

1. Ridge / Furrow Sowing 2. Broadcast 3. Line sowing 4.Others, pl. specify [_______]

C/21 Varieties Sown

Name of Variety	Acres sown	Seed / Acre (Kgs)	Total Cost	Cost / acre
[____________]	[____________]	[__________]	[__________]	[_//______]
[____________]	[____________]	[__________]	[__________]	[_//______]
[____________]	[____________]	[__________]	[__________]	[_//______]

C/22 Please give reasons for planting these varieties from the below choices [______]

1. High yielding	
2. Insect pest resistant	
3. High value in market	
4. Recommended by Agri. Department	
5. Only this variety available	
6. Others specify [__________________]	

C/23 How do you decide about the seed rate? Please choose from the choices below [_________________]

1. Past Experience	
2. Advice from the Agri. Department	
3. Advice from input dealer	
4. Any other [__________________]	

C/24 Have the germination been tested prior to sowing [________] 1. Yes 2. No

C/25 What is the approximate germination percentage (%) [_____________________]

C/26 Do you carry out the thinning operation [_______] 1. Yes 2. No

C/27 What is the approximate plant to plant distance in feet [____________________]

C/28 What is the approximate row to row distance in feet [_____________________]

C/29 Total plant population in an acre [____________________________________]

D/ Irrigation Sources & Methods

D/1 What are your sources of irrigation, please choose from the choices below [_] [_]

1. Canals	
2. Tube wells	
3. Electric Pumps	
4. Wells	
5.Any Other	

D/2 If own Tube well then monthly electricity bill in Rupees [______] Pumps [_____]

D/3 Approximate number of hours a tube well is run every day [___________]

D/5 Total number of acres managed by one Tube wells [______________________]

D/6 If purchase water then Total cost in Rupees during season [________________]

D/7 If water is purchased then per hour cost of water [///////////___________]

D/8 If you sell water then approximate monthly income from water selling [_______]

D/9 During the season is there scarcity of water [_____] 1. Yes 2. No

D/10 If yes then how do you manage water scarcity [___]+ [___]+ [__]
1. Band making 2. Deep ploughing 3. Line Sowing 4. Others [_________________]

D/11 How much yield is affected due to water scarcity in percentage [____________]

D/12 Time of Irrigation

Please provide information about stage of cotton and the costs of irrigation.

Irrigation Number	Stage of Crop	Month Name / Irrigation interval	Cost / Irrigation	Total cost	Cost per acre
Rouni	[___________]	[___________]	[___________]		/////////////
1st	[___________]	[___________]	[___________]		//////////////
2nd	[___________]	[___________]	[___________]		
3rd	[___________]	[___________]	[___________]		
4th	[___________]	[___________]	[___________]		
5th	[___________]	[___________]	[___________]		
6th	[___________]	[___________]	[___________]		

E- Fertilizer Use Information

E/1 What is the source of fertilizer?

Please choose from the choices [_________]

1. Own	
2. Village Market	
3. Tehsil Market	
4. District Market	
5. Public / Private Agency	
6. Others [_____________]	

E/2 Are you using the recommended doses of fertilizer [_________] 1. Yes 2. No

E/3 Do you apply Farm yard manure at the land preparation time [____] 1. Yes 2. No

E/4 If Yes what is the source of Farm Yard Manure [________] 1. Own 2. Purchased

E/5 If purchased what are total cost of Farm yard manure in Rupees [_____________]

E/6 Total number of acres in which Farm yard manure was applied [______________]

E/7 Quantity of Farm yard manure applied [_______________]

E/8 Fertilizer Application

Name of Fertilizer	Stage of crop	Acreage	Quantity Applied (Bags)	Price /Bag	Total Cost	Per acre Cost
[________]	[________]	[_____]	[_____________]	[___]		//////////////// ////////////
[________]	[________]	[_____]	[_____________]	[___]		
[________]	[________]	[_____]	[_____________]	[___]		
[________]	[________]	[_____]	[_____________]	[___]		

E/9 How do you decide about the application of fertilizer? Please choose from the given Choices [_________________________]

	1. Result of Soil Test
	2. Fertilizer dealer recommendations
	3. Extension service recommendation
	4. Routine Practice (Past Experience)
	5. Price of Fertilizer
	6. Any Other [___________________]

F/10 Have you used potash fertilizer?
[_______] 1. Yes 2. No

F - Insect / Pest and Diseases Attack

F/1 Please provide information about the name of insect, pest and diseases

Name of Insect / Pest / Diseases	Stage of Crop	Name of Pesticide Sprayed	Unit (liter)	Price per liter	Total Cost	Per Acre Cost
Insects /Pests						
1. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
2. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
3. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
4. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
5. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
Diseases						
1. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
2. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]
3. [____________]	[__________]	[_____________]	[___]	[__]	[___]	[_/__]

F/2 What percentage of cotton was damaged by insect, pest /diseases during the current season. [__________________]

1- >50 %
2- 25-50 %
3- 10-15 %
4- 0-10 %
5. Others[______]

F/3 How much area was damaged by cotton leaf curl virus [___]

F/4 Do you carry out the pest scouting manually? [_] 1. Yes 2. No

F/5 If yes then frequency of pest scouting [______]

1. Daily
2. Weekly
3. Monthly
4. Once in season
5. Others [_____]

F/6 Source of pesticide Purchase

From where do you purchase pesticide? Please choose from the given choices [___]

1. Village dealer	
2. Tehsil dealer / District dealer	
3. Pesticide company man visited in the village	
4. Fellow farmers in the village do this business	
5. Any Other[___________________________]	

F/7 How do you purchase pesticides [_____________] 1. On Cash 2. On Credit

F/8 Please provide the price difference when purchased on credit, how much do you have to pay additionally in Rupees / acre

[____]

F/9 Pesticide Spray

Machine used for spray operation [______] 1=Manual hand machine 2. Tractor driven machine 3. Other [____]

F/10 Can you differentiate between harmful and beneficial pests [___] 1=Yes2= No

F/11 Recommended doses of pesticide & Timing of application [_____] 1=Yes2= No

F/12 Precautions taken during pesticide spray [__________________] 1=Yes2= No

F/13 Number of human illness due to pesticide sprays [____________] 1=Yes2= No

F/14 If human beings and animals are affected by the pesticide spray then please provide the approximate cost of treatment in Rupees [______________________]

F/15 Total number of insect / pests attacking on cotton crop [___________________]

G-/ Weeding / Hoeing Operation

G/1

Names of weeds	Controlling Method 1. With hand 2. Spray 3. With Tractor 4. Any Other	Total Cost	Cost /Acre
1. [__________________]	[__________________]	[________]	[_/_____]
2. [__________________]	[__________________]	[________]	[_/_____]
3. [__________________]	[__________________]	[________]	[_/_____]
Total Cost		[________]	[__/____]

Do you carry out the rogging/ Hoeing operation [___________] 1=Yes2= No

If yes total number of Hoeing / rogging operation during cotton season [___________]

Total cost of rogging / Hoeing operation [_____________________________________]

H- Cotton Picking

H/1 When do you start picking (What percentage of bolls are open) [______________]

H/2 Please provide name of month in which you start 1st picking [________________]

1. September 2. October 3. November 4. Others [____]

H/3 Please gives information about wage rate of cotton picking per day [__________] and per mound [___________________________]

H/4 Do you provide instructions to cotton pickers about clean picking [___]1. Yes 2. No

I- Variety-wise yield / production of Cotton

Picking Number	Variety-Wise Yield in maunds			Yield per acre (Maunds)	Total Yield (Maunds)
	Variety 1 ________	Variety 2 ________	Variety 3 ________		
1st	[______]	[______]	[______]	[___________]	[__________]
2nd	[______]	[______]	[______]	[___________]	[__________]
3rd	[______]	[______]	[______]	[___________]	[__________]
4th	[______]	[______]	[______]	[___________]	[__________]
Total	[______]	[______]	[______]	[___________]	[__________]

Total cotton yield during the last season in maunds [__________________________]
Value of yield in Rupees [____]

J- Credit Facilities / Extension Services and Membership of Farmers Group

J/1 Is credit facility available for purchase of inputs / Farming [_______]1. Yes 2. No

J/2 Have you ever received credit facility [_______] 1.Yes 2. No

J/3 If **yes** then please fill in the following table regarding credit information

Source of Credit *	Year	Amount (Rs)	Interest Rate	Purpose	Duration	Installments Number	Installments amount
	[_____]	[____]	[____]	[____]	[____]	[_______]	[_______]

*1. Formal (Banks / Govt. Institutions/ NGO's/ One window credit scheme) 2. Informal (Friends / Relatives / Commission agent)

J/ 4 Have you information about all available credit sources [_________] 1. Yes 2. No

J/5 Have any of your family member ever availed credit facility [_____] 1. Yes 2. No

J/6 Ever this happened that your application for loan was rejected [____] 1. Yes 2. No

J/7 Reason of not taking credit [____]
1. High interest rate 2. No Guarantee 3. Difficult procedure 4. Other [_____________]

Inputs Availability on Credit

J/8 Do you buy inputs on credit [________________________________] 1. Yes 2. No

J/9 If yes then names of inputs taken on credit

1. [__________] 2. [__________] 3. [__________] 4. [__________]

J/10 Prices at which offered in Rupees

1. [__________] 2. [__________] 3. [__________] 4. [__________]

J/11 Market Price of the Inputs in Rupees

1. [__________] 2. [__________] 3. [__________] 4. [__________]

J/12 Difference in Price

1. [__________] 2. [__________] 3. [__________] 4. [__________]

Farmer's Membership

J/13 Are you a member of any organization [__________________] 1. Yes 2. No

J/14 If yes then please provide the following information

Organization Name	Membership Year	Meeting Frequency / month
[________________]	[________________]	[_______________________]

J/15 Benefits from the organization [______] [________], Please use codes

1. Information 2. Marketing help 3. Credit 4. Extension advice 5. Others [______]

Farmer's Source of Information

J/16 Do agriculture extension department visit you [________] 1. Yes 2. No

J/17 If yes then Frequency of visit [____________] 1. Weekly 2. Monthly 3. Once / season 4. Never

J/18 Have you ever visited extension office for information? [______] 1. Yes 2. No

J/19 Do you know about the location of the extension office [______] 1. Yes 2. No

J/20 Most popular source of information, Please fill below by choosing from the following choices (1. TV 2. Radio 3. Newspaper 4. Extension agents 5. Fellow Farmers 6. Any Other [________]

1. [__________] 2. [__________] 3. [__________] 4. [__________]

J/21 Ranking of Problems / Constraints or Lack of Information

Lack of Information/Constraints/ Problems	Please cross [x] the Constraints by severity					No [x]
	Very High	**High**	**Medium**	**Low**	**Very Low**	
Lack of Production Technology Information	[___]	[__]	[_]	[_]	[__]	[_]
High Price of Inputs	[___]	[__]	[_]	[_]	[__]	[_]
Poor Quality of inputs	[___]	[__]	[_]	[_]	[__]	[_]
Lack of guidance from extension department	[___]	[__]	[_]	[_]	[__]	[_]
Severe attack of insect, pest and disease	[___]	[__]	[_]	[_]	[__]	[_]
Lack of information about Support Price	[___]	[__]	[_]	[_]	[__]	[_]
Non availability of credit facility	[___]	[__]	[_]	[_]	[__]	[_]
Less market prices of cotton	[___]	[__]	[_]	[_]	[__]	[_]
No crop Insurance system	[___]	[__]	[_]	[_]	[__]	[_]
No Government Purchasing points	[___]	[__]	[_]	[_]	[__]	[_]
Non availability of Transport	[___]	[__]	[_]	[_]	[__]	[_]
Lack of information about IPM Programme	[___]	[__]	[_]	[_]	[__]	[_]
Bad weather during cotton season	[___]	[__]	[_]	[_]	[__]	[_]
Non availability of Official Bt cotton seed	[___]	[__]	[_]	[_]	[__]	[_]

J/22 Percentage of crop destroyed due to bad weather [______________________]

K- Labour Availability and Wage Rates

K/1 Do you hire labour for your farm activities? [______________] 1 =Yes, 2 = No

K/2 What is your source of labour for farm activities and how much do you pay for hired labour

Activity	Source of labour	No. of days per season	Hours per day	No. Of hired labourers	Wage rate (Rupees)	Unit 1=day 2=month 3= acre 4= other
Land preparation	[___]	[____]	[___]	[______]	[_________]	[______]
Seed Sowing	[___]	[____]	[___]	[______]	[_________]	[______]
Weeding	[___]	[____]	[___]	[______]	[_________]	[______]
Hoeing	[___]	[____]	[___]	[______]	[_________]	[______]
Irrigation	[___]	[____]	[___]	[______]	[_________]	[______]
Fertilizer	[___]	[____]	[___]	[______]	[_________]	[______]
Pesticide Spray	[___]	[____]	[___]	[______]	[_________]	[______]
Cotton picking	[___]	[____]	[___]	[______]	[_________]	[______]
Marketing	[___]	[____]	[___]	[______]	[_________]	[______]
Others ______	[___]	[____]	[___]	[______]	[_________]	[______]

K/2 Source of labour

1= Male Family member 2= Female Family member 3=Male hired labour

4=Female hired labour 5. Others [___________________________]

K/3 What is the wage rate per day during the cotton season in Rupees [__________]

K/4 Wage rate during the off-season in Rupees [________]

K/5 Are female labourers for cotton picking are easily available [______] 1. Yes 2. No

K/6 Is the wage rate same for male and female [____________] 1. Yes 2. No

Disposal of sticks

K/7 How do you dispose-off sticks [___] 1.Burn 2. For home use 3. Others [______]

K/8 What is the approximate value of the Sticks in Rupees [____________________]

IPM Questions

K/9 Deep ploughing of soil [__________________________________] 1. Yes 2. No

K/10 Planting of Okra [______________________________________] 1. Yes 2. No

K/11 Planted only recommended varieties [______________________] 1. Yes 2. No

K/12 Before cutting of stubbles goats has the goats been grazed [____] 1. Yes 2. No

K/13 Has the cotton sticks been put under sun for drying [________] 1. Yes 2. No

Marketing System

L/1 Cotton Selling Decision Making

Please choose from below where you sold cotton crop during 2006-07

[__________] [___________]

A	1. To Commission agent at farm gate
	2. To pesticide company at farm gate
B	3. To tehsil / district Market (Town Market)
	4. To government purchasing point
	5. Any other (specify) [_________________]

L/2 Where did you sell during the last year [________________] [_______________]

L/3 Cotton Production and Sale for year 2006-07

Selling Agency	Total Quantity Sold	Price per mound	Total Price received
A- Farm Gate	[_____________]	[____________]	[_____________]
B- Market	[_____________]	[____________]	[_____________]

L/4 Is there variety-wise difference in Prices? [___________________] 1. Yes 2. No

L/5 If yes What is the difference in prices between highest and lowest varieties [____]

L/6 Which variety have more market value [________________________________]

L/7 Time of Selling

After 1st Picking 1=Yes 2= No	After 2nd Picking 1=Yes 2= No	After 3rd Picking 1=Yes 2= No	After 4th Picking 1=Yes 2= No	After all Picking 1=Yes 2= No
[__________]	[__________]	[__________]	[__________]	[__________]

L/8 Sell when the prices are highest [____________________________]1. Yes 2. No

L/9

Normally when do you make decision about the marketing of cotton [__________________]

1. Before Sowing	
2. During season before harvesting	
3. After harvesting	
4. Other please specify [___________]	

Quality

L/10 Does the cotton price vary with quality [______________________]1. Yes 2. No

L/11 How do you take care of quality, please choose from the choices [__]+ [__]+ [_] 1. Care while handling 2. Give instructions to pickers for clean picking 3. Manual cleaning

L/12 Relationship between Quality and Price

Quality * [______]	Price received for 1 maund	Maximum Price offered (excellent quality)	Difference in Price b/w price offered and received
[______]	[______________]	[_____________]	[_///////____________]

* 1= Excellent clean from dust, leaves and other materials etc. 2= Very Good there is one part that is very little affected, over all looks good 3=Medium, almost one third is filled with small leaves and dust 4= Poor a lot of mixing of dust and leaves

L/13 Price Fluctuations during the Season

Price (Tick)	Early Season	Middle Season	Late Season	Variation in Rates 1= Daily 2=Weekly 3=Monthly 4=No variation
Farm gate	[____]	[____]	[____]	[____________________________]
Market	[____]	[____]	[____]	[____________________________]

Weights / Balances Used & Packing Material

L/14 What are the sources of weight / balance [___] 1. Own 2. Commission agent 3. Market agent

L/15 Are you satisfied with the weight / balance [________________] 1= Yes 2= No

L/16 Do you pack cotton in bags / packing material [_______________] 1. Yes 2. No

L/17 If yes then total cost of packing material [___________________________]

M- Credit / Advance/ Token money Taken from Commission Agent

(Please fill the following information only if the farmer sells to the commission agent / farm gate if the farmer sells at the market switch to part N)

M-1 Have you obtained credit / Advance /Token money from commission agent?

[____] 1. Yes 2. No

M-2 Amount of credit / Advance /Token money in Rupees [____________________]

M-3 Total number of commission agents / factory person visiting during the season [_]

M-4 Do you sell cotton to the same commission agent each season [____] 1. Yes 2. No

M-5 Timing of agreement with the commission agent [__] 1. Before harvesting 2. After harvesting

M-6 Agreement with commission agent [_________________] 1. Verbal 2. Written

M/7 Do you receive all the payment at the selling time [____________] 1. Yes 2. No

M-8 If **not** then total number of instalments in which the payment received [______]

Selection of Commission Agent

M-9 Please inform that which things you mostly consider while selecting the commission agent, Please fill from the below choices [____________________]

1. Reputation of the Commission agent
2. Previous Years Experience
3. Rate Offered by the commission agent
4. Friends / Relatives Relation with the commission agent
5. Any other, pl. specify[________________________]

M-10 Have ever commission agent defaulted [_______________] 1. Yes 2. No

N/1 Reasons of selling at the farm gate (complete only if farmer sell at farm gate)

Reasons of Selling at the Farm Gate	Please evaluate the reason **Very High**	**High**	**Medium**	**Low**	**Very Low**	Not a reason
Less Production	[___]	[___]	[___]	[_]	[__]	[___]
Transportation costs are high	[___]	[___]	[___]	[_]	[__]	[___]
Non availability of Transport	[___]	[___]	[___]	[_]	[__]	[___]
Market is at far off place	[___]	[___]	[___]	[_]	[__]	[___]
There is not much difference in Price	[___]	[___]	[___]	[_]	[__]	[___]
Taken credit from commission agent	[___]	[___]	[___]	[_]	[__]	[___]
Purchased inputs on credit	[___]	[___]	[___]	[_]	[__]	[___]
Shortage of labour at marketing time	[___]	[___]	[___]	[_]	[__]	[___]
Sometimes while marketed less rates are offered	[___]	[___]	[___]	[_]	[__]	[___]
No information about market prices	[___]	[___]	[___]	[_]	[__]	[___]
No storing place available	[___]	[___]	[___]	[_]	[__]	[___]
Immediate need of money	[___]	[___]	[___]	[_]	[__]	[___]
Quality is not good	[___]	[___]	[___]	[_]	[__]	[___]

Transport Availability for Marketing

(Please fill the following information only if the farmer has sold the cotton in the market)

O-1 Mode of Transport

Mode*	Fare 1 Round Trip	Weight Carried in 1 Trip (maunds)	Own Transport 1= Yes 2=No	If hired then source from where transport was hired 1= Friends and relatives 2= Same village farmers 3= Other village farmers	Non Availability 1. Yes 2. No
[___]	[___]	[_______]	[________]	[____________________]	[________]

Mode* 1. Tractor Trolley 2. Truck 3. Animal Cart 4. Any Other (Pl. Specify) [_________]

O-2 Total transport visit to the market for cotton marketing [____________________]

O-3 Difference in fare during cotton season and off-season in Rupees [____________]

Taxes paid while selling at Market / Factory

O-4 Do you have to pay Chungi / Zila tax while travelling to market [__] 1. Yes 2. No

O-5 If yes then amount of tax paid in Rupees [_____] weight for which tax paid [_]

O-6 Do you have to pay Thara tax / place tax in the market [________] 1. Yes 2. No

O-7 If yes then amount of tax paid in Rupees [___] Quantity of Cotton for which tax paid[____]

O-8 Please mention name and amount of any other tax paid [______] [______]

O-9 Distance of nearest market

Please provide information about the distance of nearest market in kms [__________]

P- Sources of Income

P/1 Please provide information about your primary source / main source of income, choose from the below choices [_______________]

1. Agriculture, 2. Business, 3. Employment, 4. Labour 5. Others [__________]

P/2 Are you also doing off-farm work [_____________] 1. Yes 2. No

P/3 Approximate per day time spent on off-farm work [_____________________]

	Agriculture	Employment	Business	Others
# of Family members engaged	[_______]	[_________]	[______]	[______]
Income per month	[_______]	[_________]	[______]	[______]
Income per season	[_______]	[_________]	[______]	[______]
Income Year	[_______]	[_________]	[______]	[_______]

Q-1 Problems in Cotton Production and marketing

1.____

____

____

2.____

____

____

3.____

____

____

Q-2 Suggestions to improve Cotton Production and Marketing System

(Suggestions at village level, institutional level and national level etc.)

1.____

____

____

2.____

____

____

3.____

____

____

(Please say Thanks to dear farmer for his time and useful information).

Appendix B: Curriculum Vitae

Name:	Akhter Ali
Date of Birth:	1st April 1975
Place of Birth:	Multan, Pakistan
Nationality:	Pakistani
Marital status:	Married

Education

2006-2010:	PhD student at the Department of Food Economics and Consumption Studies at the Christian-Albrechts –University Kiel, Germany. Thesis title: "Impact of Land Tenure Arrangements, Bt Cotton Adoption and Market Participation on Welfare of Farm Households in Rural Pakistan".
1998-2001	M.Sc. (Hons.) in Agricultural Economics, University of Arid Agriculture, Rawalpindi, Pakistan. Thesis title: "Profitability of Groundnut, Sunflower and Canola Crops in Rawalpindi and Chakwal Districts".
1994-1998	B.Sc. (Hons.) in Agricultural Economics, University of Arid Agriculture, Rawalpindi, Pakistan.
1991-1993	F.Sc. (Pre-Medical), F. G. Sir, Syed College, Rawalpindi, Pakistan.
1980-1990	Secondary School Certificate, Government Abbasi High school, Rawalpindi, Pakistan.

Professional Experience

October 2006- June 2010
Doctoral student at Christian-Albrechts- University Kiel, Germany.

Since November 2002
Working as scientific officer at Pakistan Agricultural Research Council (PARC), Islamabad, Pakistan (Currently on leave due to PhD studies).

April 2002-November 2002
Worked as social organizer at National Rural Support Programme (NRSP), Gujar, Khan, Rawalpindi, Pakistan.