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The Influence of Neighbors in Technology Adoption: Evidence from Farmers in Pakistan and Malawi

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The Influence of Neighbors in Technology Adoption: Evidence from Farmers in Pakistan and Malawi

by

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Dedication

Professor Alamgir M. Serajuddin, my father, who began teaching me on a small blackboard when I was a child

and

Professor David C. Colander of Middlebury College, whose teachings, kindness, and generosity have blessed my life.

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The Influence of Neighbors in Technology Adoption: Evidence from Farmers in Pakistan and Malawi

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This dissertation analyzes the importance of *economic* and *information* related barriers to technology adoption, with an emphasis on the role of interpersonal information exchange among social and physical neighbors. The two studies that make up the dissertation are based on the IFPRI Pakistan Panel Survey, 1986-91, and the Malawi Integrated Household Survey, 1997-98. Our research attributes communication or information factors for the slow adoption of new high yield variety (HYV) wheat seeds in Pakistan, and economic or production constraints for the slow adoption of hybrid maize seeds in Malawi. In Pakistan, the usual economic or production related constraints do not appear to hinder adoption since capital requirements for the new technology are only modestly higher. Rather, the slow adoption of new HYV seeds is attributable to a paucity of reliable information regarding the subtle advantages of the new technology. Conversely, in Malawi, the new hybrid maize seed technology is starkly superior to the previous technology, and though farmers are cognizant of these conspicuous differences, they lack the capital to make the conversion.

The Pakistan study shows that farmers' attitudes toward the adoption of new HYV wheat seeds are inter-dependent. Interestingly, farmers appear to be more strongly influenced by their *social peers* rather than *physical neighbors*. Social peers are defined as farmers within the same village who share similar economic and social standing, i.e., belong to the same land ownership group. However, there is no evidence of such learning externalities across farmers in different socioeconomic (land ownership) groups. This segregated communication network can potentially lower economic productivity – farmers communicate less across socioeconomic classes contributing to the slow diffusion of new productivity-enhancing technologies. Since the local societal setup in Malawi does not lend itself to a socioeconomic definition of neighbors, the Malawi study focuses on physical neighbors only. We find that physical neighbors likely do not strongly influence household adoption decisions in Malawi. Our findings are consistent with the contrasting agricultural environments in Pakistan and Malawi and reflect the different stages of agricultural development and the distinctive characteristics of the new technologies introduced in these two countries.

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Chapter 1

Introduction

Agricultural technology plays a particularly vital role in developing countries where the majority of the population is dependent on agricultural production. Development economists and policymakers have long considered the adoption of new agricultural technologies as an important means for increasing agricultural production and stimulating economic growth. Productivity differences across regions can be explained by disparities in the adoption of new technologies, and most of the cross-country variation in income comes not from differences in capital or labor inputs but from differences in total factor productivity (Skinner and Staiger 2005; Caselli and Coleman 2004). Among agricultural technologies, high yield variety seeds and hybrid seeds, which powered what is known as the Green Revolution, perhaps have been studied most keenly.

The present work analyzes the socioeconomic and information related factors that could potentially facilitate or impede the adoption of new seed technologies, and it identifies potential public policy initiatives that could encourage adoption. A major contribution of this dissertation is the analysis of the interdependence of different farmers' attitudes toward new technologies, a subject that has been quantitatively studied only recently. When a new technology becomes available, potential adopters may learn about the technology and its efficacy through their neighbors' attitudes and actions. This dissertation explains the nature and extent of the influences of neighbors on a farmer's ultimate adoption decision using farm household level adoption data.

Technological developments over the last century have transformed agricultural production from being mainly resource-based to being largely technology-based. Before the twentieth century, almost all the increases in agricultural output resulted from increases in arable land. In the twentieth century, however, most increases in output came from increases in agricultural productivity (i.e., higher yield per unit of land). This phenomenon was attributed to technological innovations in machinery (e.g., tractors), improved varieties of seeds (e.g., HYV seeds), the introduction of pesticides and fertilizers, and new management techniques. While this transformation began in the last quarter of the nineteenth century in the United States and other currently developed countries, most developing countries began experiencing a similar transformation around or after the mid-1950s (Ruttan 2003). Beginning in the 1960s, the Green Revolution rapidly became a major success in much of Asia. Rapid adoption of modern variety wheat and rice seeds led to spectacular increases in productivity, helping ease mass starvation and rural poverty. In a report titled "Modern Varieties, International Agricultural Research, and the Poor", Michael Lipton (1985) made this point rather dramatically: "If the farmers today used the same cereal varieties as in 1963-64, and everything else were unchanged, then tens of millions of people would this year die of hunger."[1]

The success of the Green Revolution in Asia in the late 1960s and the 1970s also generated enthusiasm about the promise of new technologies in Sub-Saharan Africa, a region beset by environmental degradation, population growth, and natural and man-made disasters. Unfortunately, the spread of new agricultural technologies in Sub-Saharan Africa has been sluggish, and despite the great promise of these new technologies, in many cases,

[1] We take this quote from Wolf (1986, p.15).

the promise has remained unfulfilled (Sanders et al 1996). In his description of the differential impacts of the Green Revolution across countries, Evenson (2004, p.548) writes: "The production increases enabled by the Green Revolution in the aggregate in developing countries constitute a 'global' success, but for a number of countries, the Green Revolution represents a 'local' failure."

Technology adoption, agricultural or otherwise, is often not a frictionless process, even when the new technology is superior from a productivity standpoint. Its nature and dynamics are rather complex, with adoption behavior varying significantly across individuals and groups. This has resulted in strong intellectual and policy interest in this area.[2] Rural sociologists, communications theorists, geographers, and economists have explored this issue extensively from perspectives that are both competing and complementary. Traditionally, agricultural economists researched farm household-level technology adoption by focusing on the roles of production related factors such as land size, land tenure arrangements, the availability and cost of complementary inputs, labor market conditions, access to credit, and access to markets and infrastructure. Economists also have analyzed the role of human capital and public information sources in adoption (see, for example, Feder et al 1985). Rural sociologists, early enthusiasts of the subject of technology adoption, were interested in how the availability of information and communication patterns across individuals affected adoption. In the last ten years, economists have turned their attention to the role of interpersonal information exchange in adoption decisions; previously, this factor was largely ignored by them.

[2] According to Rogers (1962, p.1), the study of adoption is interesting because "getting a new idea adopted, even when it has obvious advantages, is very difficult."

When a new technology becomes available, its attributes and applications are not always transparent to potential adopters. Consequently, there are uncertainties associated with the adoption of a new technology. Potential adopters can reduce these uncertainties by familiarizing themselves with the new technology through public information sources such as agricultural extension offices or the mass media. They may also seek information from informal sources such as observing neighbors' attitudes and actions. Information gathered from interpersonal exchanges, which encompasses both learning from others and simply imitating others, has externalities. In this respect, interpersonal exchanges are distinct from information gathered from other sources. The externality arises because an individual's knowledge and opinions about a technology, apart from being personally beneficial, also benefits other individuals who come in contact with him or her. Estimating the externalities from learning or information exchange can give us a sense of how individuals communicate with others and the extent to which they are influenced by each other. In the present work, two concepts of neighbors are explored – one is based on geography and the other is based on a socioeconomic concept of neighbors. Distance or disparity among individuals appears to be an important factor in social interactions, be it geographical distance or some form of a *social distance* or disparity.

Both Pakistan and Malawi are low-income countries with agriculture being the most prominent economic sector. Wheat is Pakistan's staple food and maize is the staple food in Malawi. Both countries struggle to maintain stable supplies of their staple foods and policymakers have made efforts at promoting new crop varieties to increase outputs. To empirically analyze the technology adoption process, this dissertation studies two separate cases of the adoption of agricultural technologies: (1) adoption of new vintages of High Yield Variety (HYV) wheat in Pakistan, and (2) adoption of hybrid maize in Malawi. These two cases are not only very interesting exemplars of household adoption behavior, but they also allow for a conceptual study of the differential nature of the Green Revolution in Asia versus Sub-Saharan Africa.

While both countries are poor, Pakistan's agricultural production system is relatively more advanced and mechanized than Malawi's agricultural practices. HYV wheat was introduced in Pakistan in the late 1960s and within a few years it had replaced traditional wheat varieties, and thus, the Green Revolution was considered to be a success in Pakistan. Over time, different vintages of HYV wheat have been introduced in Pakistan, but, while initial adoption of HYVs was rapid, subsequent adoption of *newer* HYV wheat varieties (replacing older HYV seed varieties) has been slow. This study focuses on households' adoption of newer versus older varieties of HYV wheat in Pakistan during the period 1986-89 using a household level panel dataset. In Malawi, the Green Revolution came rather belatedly as it was only in the 1990s that hybrid maize suited to the consumption needs of the local people was introduced. Low maize output has been a cause of major frustration in Malawi where per capita maize consumption is one of the highest in the world. However, by the late 1990s, only about half the population in Malawi had adopted hybrid maize, even though it had almost three times the yield of traditional maize. The Malawi study of hybrid maize adoption is based on a cross-sectional household survey dataset from 1997-98.

Pakistan and Malawi are in different stages of agricultural development, and the environments and the technologies in question are very different. Therefore, one must be careful to draw common conclusions from them. Yet, interesting lessons can be learned from the adoption behavior of households that can greatly aid in the understanding of household adoption behavior in low-income countries. In Pakistan, the new technology in question was superior to the older technology but the differences in the two technologies were subtle. Our findings indicate that the usual production related constraints did not appear to hinder adoption in Pakistan since the capital requirements of the new technology were modestly different from the older technology; rather it was the paucity of reliable information that slowed adoption since farmers were not fully aware of the desirable characteristics of the new technology. In the case of Malawi, the new technology was clearly superior to the older technology, and farmers appeared to be aware of these conspicuous differences. Our findings for Malawi contrast the Pakistan study findings, i.e., adoption in Malawi was slow due to production related variables, and not so much due to information related factors as in the Pakistan study. Even if farmers had the will to adopt, they did not necessarily have the ability to adopt. Our research thus attributes communications factors for the slow adoption of new HYV wheat seeds in Pakistan, and economic constraints for the slow adoption of hybrid maize seeds in Malawi.

The Pakistan study is based on panel data and the Malawi study is based on cross-section data, which makes the empirical analysis for these two studies different. Cross-sectional studies provide a snapshot of the adoption process by giving a sense of how "the technology may be incompletely diffused through the population" at a particular point. (Besley and Case 1993, p.397) Cross-sectional studies cannot, however, take into account the dynamic component of the adoption process. Conversely, panel data are better suited to get a more complete picture of the adoption process. While the Pakistan dataset is smaller than the Malawi dataset, its temporal component enables it to more fully address the dynamics of the adoption process. The Malawi dataset, on the other hand, gives insights into the importance of different factors in adopting the technology at a single point in time. Moreover, the Malawi dataset is partially immune to typical criticisms of cross-sectional studies as the dataset was not collected during the early stages of hybrid maize introduction but by the time it was a 'mature' technology. This dissertation draws inferences from these two different datasets and illustrates the strengths and weaknesses of each case.

In this dissertation, we explore a particular concept of socioeconomic neighbors in detail by defining neighbors along individual wealth levels. Economic position is a consequential part of one's identity and differences in wealth could be a good indicator of socioeconomic differences (Esteban and Ray 1994). Even casual observation suggests that wealthier households tend to interact with other wealthy households more so than with relatively poorer households. Similarly, poorer households tend to interact more with other poor households. In such cases, households are more likely to be influenced by the adoption behavior of their social peers or neighbors with similar income levels. The wealth effect would be more pronounced in societies where wealth is strongly linked to class and if communication patterns are stratified along class lines. Several studies have defined neighbors based on individual characteristics such as ethnic or religious groups (e.g., Conley and Topa 2002, Munshi and Myaux 2005). However, the definition of neighbors based on economic wealth, which is explored in this study, is a new contribution to the literature on neighbor influences. Communication based on socioeconomic traits such as wealth could provide insights into broader policy issues, e.g., if it is in fact the case that individuals across different wealth groups communicate with each other less effectively, and this adversely affects adoption, wealth inequality can be inferred to cause economic inefficiency.

To explore the concept of socioeconomic neighbors in the Pakistan study, we divide households into different neighbor groups depending on their land ownership since it is a good indicator of wealth in rural Pakistan and our fieldwork indicated that land groupings are an effective concept to study social interactions. The results of our empirical analysis further reinforce this observation. We found that social interactions take place largely along landholding groups and there is no evidence of substantial cross-group influences. Given Malawi's social context, we only explored the role of physical neighbors. The concept of socioeconomic neighbors is weak in Malawi since within a locality, social differences are not very pronounced. Rather, such differences are pronounced across localities.

The rest of this dissertation is divided into five chapters. Chapter 2 provides an overview of adoption literature showing how the discipline evolved over time with sociologists and economists at first pursuing competing approaches to the discipline, but later developing certain complementary approaches. Chapter 3 describes and motivates various factors that influence adoption. It discusses how the production related factors and the information related factors influence adoption behavior, with a special emphasis on the role of neighbors. This discussion is followed by detailed analysis of the Pakistan and Malawi case studies. The Pakistan study on HYV wheat seed adoption is developed in Chapter 4, which highlights the role of information related constraints in the slow adoption of new HYV wheat seeds. Research indicates that on the whole, farmers were not fully aware of the potentially beneficial attributes of the new HYV seeds, and therefore, were slow to adopt, often even if they had the financial means to do so. Chapter 5 discusses the adoption of hybrid maize in Malawi and discusses the importance of economic constraints in adoption. In Malawi farmers appeared aware of the superiority of the hybrid maize seeds over the traditional seeds, but could often not muster the economic resources necessary to adopt hybrid seeds. Chapter 6 concludes with a synthesis of the findings of the dissertation. Our findings from the two studies indicate that both production and information related factors potentially drive adoption behavior in different ways, and that the relative importance of the two categories is context specific.

Chapter 2

Review of Adoption Studies

Research on technology adoption gained strong interest among sociologists, particularly rural sociologists, in the 1940s and 1950s. Adoption, in their view, depended on how well the new technology conformed to the norms of the society and on the social rewards awarded to adopters. In the late 1950s and the 1960s, economists and a small number of geographers began to take interest in adoption research. Economists' focus was primarily on the economic constraints to technology adoption, while geographers focused on adoption as a problem of differential resource endowments across space. Communications scholars also emerged technology adoption field at this time, finding common research interests with sociologists. Besides this example of cross-disciplinary fertilization, research in technology adoption during this time was constrained by respective disciplinary paradigms. Subsequently, scholars of adoption behavior have made greater efforts to collaborate across disciplinary boundaries. By the early 1990s, economists began attempting to include sociological concepts in their adoption analysis. The present work also strives to tie in economic and sociological concepts in studying the adoption process. Specifically, the approach used to analyze the adoption process is primarily empirical, with attempts to include socioeconomic considerations in the analysis.

The overview of adoption studies presented in this chapter provides an understanding of how the literature has evolved over time, and establishes a context for the present study. We first discuss the early sociology studies, which include work done by communications theorists. Then the economists' approach to the problem is discussed using earlier and more recent literature. Finally, we provide a brief synopsis of the current status of adoption research.

Rogers (1962, p.17) defined the adoption process as "the mental process an individual passes from first hearing about an innovation to final adoption." He described a five-stage adoption process that an individual, firm, or any other decision-making unit undergoes by (1) gaining knowledge about the new technology; (2) forming an attitude towards it; (3) deciding whether or not to adopt; (4) implementing the decision (to adopt or not adopt); and (5) confirming that decision (i.e., the individual seeks to test whether this was the right decision; if not, he/she would then see if the decision could be reversed). For the purposes of empirical or theoretical work, more quantitative definitions of adoption need to be considered, and a distinction between the individual and the aggregate level needs to be drawn. At the individual level, adoption should reflect the *degree of use* of a new technology (Feder et al 1985).[3] On the other hand, aggregate adoption is measured by the "aggregate level of use of a specific technology within a given geographical area or a given population (Feder et al 1985, p.257)."[4] This thesis focuses on the individual level adoption decision.

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[3] This definition is particularly useful in understanding agricultural technologies. A new technology might completely replace an old one. For example, a farm household might start using a new technology like HYV (high yield variety) seeds instead of local varieties. In that case adoption would be a dichotomous variable (adopt/ not adopt). It, however, can also be the case that a household grows the HYV crop on some portion of its land and the local crop on the other portion. Adoption then can be measured by how extensive the use of the HYV crop is by measuring what fraction of land is allocated to it. Another measurement associated with degree of adoption can be the frequency use of a particular technique.

[4] The term "technology diffusion" is frequently used in the literature. Rogers (1962, p. 10) defined the term technology diffusion "as the process by which (1) an innovation (2) is communicated through certain channels (3) over time (4) among the members of a social system." Diffusion can thus be viewed the same way as the aggregate adoption process.

2.1 Sociology and Communications Studies

Sociologists viewed innovation and its propagation as a process of social change. The adoption process was considered to be both a consequence of society and in turn, had far reaching social consequences. Gabriel Tarde's *The Laws of Imitation* (1903, first published in 1890) is perhaps the first detailed analysis of innovation and the adoption process. Tarde stressed imitation as a central feature of how individuals behave in society, and defined it as a driving force behind social change and the adoption of new innovations. Interdependence of human actions has been the common theme of adoption studies in sociology. By the end of the 1950s, adoption research developed in the sub-disciplines of rural sociology and medical sociology independently of each other.

Coleman, Katz and Menzel's (1957, 1966) work on doctors' decisions in adopting new prescription drugs initiated medical sociological literature on adoption. They argued that doctors tend to adopt the attitudes and norms of the group with whom they associate. It is, however, rural sociologists who pursued the study of adoption more extensively. Ryan and Gross' (1943) study of the use of hybrid corn in Iowa set the stage for this approach.[5] They interviewed 259 farmers in two small communities in Iowa and analyzed their adoption behaviors. They observed the now famous sigmoid or S-shaped curve, which describes the dynamics of adoption over time. After a new technology is introduced, initially there are hardly any users and adoption is very slow. After a certain threshold number of adopters are reached, a period of rapid adoption follows; as the number of potential adopters begins to get exhausted, adoption begins to slow down and eventually flattens out.

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[5] Vernon Ruttan (2003, p.175) describes their work as, "The socio-psychological paradigm … [that] became the academic template that was to be adopted first by other rural sociologists in agricultural diffusion research, and then by almost all other diffusion research traditions."

Rural sociologists argued that adoption exhibits such dynamics because of the nature of interpersonal information exchanges between individuals who have already adopted the technology and those who remain potential adopters. Communications scholars also subscribed to this rationale. Everett Rogers wrote *Diffusion of Innovations* in 1962, which is perhaps the most widely cited book among sociologists on the topic. Rogers classified adopters into five categories based on their differential tendency to adopt over time: (1) innovators; (2) early adopters; (3) early majority; (4) late majority; and (5) laggards. These adopter categories have different ways of functioning within society and have different ways of learning and communicating. Earlier adopters have stronger networks of communication and are more likely to seek out and act on information, whereas late adopters have weaker networks and weaker initiatives to adopt. Information is transmitted across society through "communication channels." There are two types of channels: public or mass media, and interpersonal exchange. Rogers argued that early adopters are more likely to act on information they obtain from public sources, for example, from the mass media (in the case of agricultural technologies this would include agriculture extension agents who may be a good source of public information). Later adopters are more likely to rely on the opinions of their peers. Rogers underscored the relative importance of interpersonal exchange by arguing that while public sources might be a good basis for creating awareness about new technologies, the actual adoption decision is more likely to be influenced by the attitude of fellow peers. He identified five characteristics of innovations that potential adopters consider in their decision to adopt:

i) *Relative advantage* – What benefits it offers relative to alternate options.

ii) *Compatibility* – How compatible is the innovation with the values and customs of potential adopters.

iii) *Complexity* – How easy is the technology to understand and use.

iv) *Trialability* – To what extent can potential adopters experiment with it before completely committing to the innovation.

v) *Observability* – To what extent are the results of the new technology apparent to others so that they can form an opinion about it.

The decision to adopt, therefore, is the end result of a learning process. As mentioned earlier, potential adopters learn through communication channels. They also learn from whatever personal experience they might have with the technology through trialability (what economists refer to as *learning by doing*).

2.2 Economics Studies

By the end of the 1950s, adoption research in rural sociology began to decline. A few geographers became involved in adoption research at this time, focusing on adoption as a spatial process. Swedish geographer, Torsten Hagerstrand (1967), developed a simulation approach of technology spreading from one adopter to another by probabilities that declined with distance from the earlier adopters. Adoption research, however, did not generate much enthusiasm within the discipline. It was in the field of economics that technology adoption research gained momentum beginning in the late 1950s and still continues to remain an important research area.

The pioneering work was Zvi Griliches' (1957) study of the diffusion of hybrid corn across different states in the United States. He argued that economic factors and not sociological factors were the driving force behind adoption. Griliches found S-shaped patterns of diffusion over time for the different states and linked the adoption rates of hybrid corn to its relative profitability. The S-shaped curve can be explained by "adopter heterogeneity," i.e., different individuals place different valuations on a new technology (Hall and Khan 2003). Thus, individuals who place a higher value on it (because they feel they can profit more from it) are going to adopt early. Individuals who place lower values would join in over time as the cost of the new technology declines. Individuals adopt when their perceived benefits from adopting surpass the potential costs. This approach is different from the communications based approach of sociology, where it is implicit that all individuals place similar values to the new technology but differ in their adoption decision based on how and when they receive and communicate information about it.

While Griliches (1957) did not consider learning and the communications process, subsequent economics research began to include these dimensions. Early adoption studies in the field of agricultural economics were primarily concerned with agro-economic variables such as land size and other assets, family size, age and gender composition of households, costs and availability of inputs, labor market conditions, credit availability, and access to markets and infrastructure. Feder et al (1985) provide an excellent review of these studies. The relationships of these variables to adoption are discussed in more detail in Chapter 3, which discusses various determinants of adoption. Studies in the 1970s emphasized these themes, but by the early 1980s, economists began considering the roles of learning and communication as well.

Economists conceptualized the role of learning and communication within the framework of risk and uncertainty since potential adopters face varying degrees of risk and uncertainty. Risks individuals face can be classified into two groups: objective and subjective (Feder et al 1985). New technologies that are more prone to objective risks, i.e., risks individuals cannot influence, are of less appeal to potential adopters. Weather variations such as excessive rainfall or droughts, exposure to pests, and uncertainty of input supply and price dampen the tendency to adopt even if the new technology is expected to increase mean production. Likewise, subjective risks, which are associated with an individual's *perception* of a new technology, can also influence the adoption of a new technology. Greater information and knowledge about the technology would reduce subjective risks. Individuals may obtain information from (i) experimentation, (ii) individual human capital, (iii) public sources, and (iv) interpersonal exchange.

Studies that analyze the role of experimentation or "learning by doing" use Bayesian models of learning, with individuals updating their beliefs of the characteristics of a technology over time based on experimentation. Individuals gain in two ways from experimentation: i) their skills in using the technology improve; and ii) the uncertainty surrounding the technology lessens. As long as the technology remains profitable, individuals' favorable experiences over time will ultimately induce them to adopt it (Feder and O'Mara 1982; Besley and Case 1994).[6] Subjective risks may also be reduced through individual human capital attributes since understanding and using new technologies typically require a certain level of expertise or skill. A higher level of education or a better

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[6] Stoneman (2002) puts forth another approach to the role of uncertainty. He argues that as technology adoption is an investment under uncertainty it could be analyzed using Dixit and Pindyck's (1994) "real options" framework. Adopting a new technology entails certain irrecoverable costs. Also, the benefits/profits from adopting a new technology are uncertain in nature. Faced with these two facts, at every period in time a potential adopter may choose to adopt the technology or simply choose to defer the decision for later. The adoption decision is akin to a call option that can be exercised anytime. Thus there is an option value to waiting and adoption need not take place the instant benefits from it equal the costs. Rather it takes place when benefits to some extent are above costs. This is a cause for slower adoption.

understanding of local agricultural practices would typically be associated with a higher skill level, and would give individuals greater confidence to adopt (Schultz 1981).

Public sources of information, such as radio, television, and newspapers are an important communication channel through which potential adopters can reduce their subjective risks. In agriculture an important source of public information is local agricultural extension services, and studies have frequently viewed it as an indicator of access to public information (e.g. Birkhaeuser et al 1991; Bindlish and Evenson 1997).

Apart from personal experience, human capital, and information gained from public sources, individuals tend to be influenced by the behavior and experience of others in their local and socioeconomic surroundings. Economists, however, for a very long time virtually ignored the study of interpersonal exchange and social structure.[7] Typically, the role of interaction with one's neighbors or members of the same social group was not included in adoption studies. This contrasts strongly with sociologists' adoption studies that found ample evidence of the significance of social interactions. For instance, Rogers and Shoemaker (1971) argued that, in the diffusion of hybrid corn, while farmers became aware of the new seed from a salesperson, their actual adoption decision was influenced by what neighbors' did. A few applied economists did consider interaction between individuals as an important factor. For example, in their study on the adoption of chemical pesticides, Mueller et al (1986) found that 90 percent of farmers surveyed had discussed their decision to adopt with other farmers or extension agents. Foster et al (1987) also observed that farmers

[7] Akerlof (1997, p.1005) writes: "Traditional economics has been based on methodological individualism. Until quite recently, with some rare exceptions, it has not been appreciated that this method can be, or perhaps I should say *should be*, extended in describing social decisions to include dependence of individuals' utility on the utility or actions of others."

reported their communications with each other to be very useful and informative. These studies, however, were descriptive in nature and lacked theoretical foundations.

Individuals might adopt a technology because they learn about it from their neighbors or they may simply be imitating their neighbors. Economics studies on the role of interpersonal exchange in technology adoption fall into two categories – studies that follow the role of *information* from neighbors and studies that analyze the influence of *knowledge* gained from neighbors. The former category of studies looks broadly at the overall influence of neighbors – encompassing both learning from neighbors and simply imitating them. The latter category of studies concentrates specifically on the effects of learning from neighbors or *social* learning.

Anne Case (1992) was one of the first to formally incorporate neighbor influence in technology adoption. She used the 1980 Indonesian socioeconomic survey to analyze the adoption of sickle as a tool in harvesting rice among rural households in Java. The novelty of the study was its application of a spatial econometric framework to estimate neighbors' influence. Individual interdependencies were incorporated into the econometric analysis very directly: a household's dependent variable was its decision to adopt or not to adopt and its explanatory variables included variables reflecting whether or not its neighbors had adopted the technology. Case defined a neighborhood by individuals who belonged to the same district, and assumed that all individuals living in a neighborhood influenced each other equally. Using this specification, neighbor influences were found to be positive and significant.[8] Case's work defined neighbors in terms of geographical space and was perhaps

[8] One of the earliest adoption studies in economics by Mansfield (1961) did focus on the role of copying or imitation in the diffusion of technologies among firms. So, from an early stage, a few economists made

limited in what it could say about the nature of social interactions. It did, however, provide evidence that local level interactions can matter and can produce externalities. Neighbors can be defined in other dimensions such as income, ethnicity, and class, and Case's geographic neighbor approach can be used to estimate the importance of *income-neighbors* and *ethnic-neighbors* in adoption decisions.

Another interesting approach to studying neighbor influences was Pomp and Burger's (1995) study of cocoa adoption in Sulawesi, Indonesia. They measured the influence of neighbors using the cumulative proportion of adopters in a particular village and found it to be an important factor in adoption. They argued that the larger the number of households in a village that already grow cocoa, the larger the scope for others to observe these households and copy their behavior.[9] So far, most of the empirical work on adoption in economics has defined neighbors in geographical terms. One of the exceptions is Romani (2002) who considered ethnicity as the reference network group of households in Cote d'Ivoire. Bandiera and Rasul (2004) also went beyond defining neighbors in geographic terms in their study of sunflower seed adoption in Northern Mozambique. They found that adoption decisions were more highly correlated within the network of family and friends than within religious networks. They also found adoption decisions to be uncorrelated among individuals belonging to different religions networks.

attempts to include sociological variables in their analysis. Mansfield's work was later criticized for lacking a solid microeconomic foundation.

[9] Using village averages as a proxy for individual level information exchanges can give rise to what Manski (2000, p.128) refers to as the reflection problem: "This identification problem arises because mean behavior in the group is itself determined by the behavior of group members. Hence, data on outcomes do not reveal whether group behavior actually affects individual behavior, or group behavior is simply the aggregation of individual behaviors." Brock and Durlauf (2002), Manski (1993) and Moffitt (2001) suggest models to mitigate this identification problem. Romani (2002) attempted to avoid this problem by dropping the conventional average effect approach to social networks and instead developing a variable that expressed the probability of each farmer's accessing knowledge through his/her participation in a network and his/her ethnic characteristics.

A criticism of such studies is that while they might be demonstrating the importance of interactions among neighbors, these correlations might have other explanations as well (Manski 1993, 2000). Correlations might result because of unobservable spatially and serially correlated variables such as common shocks that individuals in a neighborhood might experience (e.g., weather shocks), or because of common traits across individuals. These issues could muddle attempts to isolate the impact of social interactions and cause an identification problem. This problem is particularly stark in the case of cross-sectional studies. With panel data, household Fixed Effects can be controlled for and this problem can be dealt with better provided that the timing of social interactions is properly specified (e.g., see Udry and Conley 2003, Bandiera and Rasul 2004).

As mentioned before, individuals might adopt a technology because they learn from their neighbors about it or they simply imitate them. A study like Case (1992) does not differentiate between these two cases. Economists, however, have tried to isolate the role of social learning. Foster and Rosenzweig (1995) identified learning from neighbors by associating learning with productivity increases. They assumed that increases in individual productivity over a period of time suggested social learning whereas non-increases suggested the absence of such learning (or mimicking/imitating). Their study used data from the onset of India's Green Revolution (1968-71) to relate village level average figures to social learning and found strong evidence that friends and neighbors were important in influencing adoption.[10] In a recent paper, Udry and Conley (2003) analyzed the dynamics of social learning in the adoption of a new set of technologies in pineapple production in Ghana.

[10] Foster and Rosenzweig (1995) analyzed learning by doing as well as social learning. Munshi (2003) is another study that found evidence of social learning in technology diffusion in the Indian Green Revolution.

They modeled the change in individual farmers' use of fertilizer in response to the fertilizer productivity of their neighbors. They found that a farmer would increase his use of fertilizer if his neighbors had experienced higher than expected profits using more fertilizer than he had used. Conversely, a farmer would decrease his use of fertilizer if his neighbors had experienced higher than expected profits using less fertilizer than he had. This indicated a strong social learning process. Udry and Conley (2003) make great efforts to get around the identification problem pointed out by Manski (1993) by gathering detailed information on the relevant neighbors of individuals and their interaction patterns with them. They found very strong signs of information flow among neighbors about fertilizer productivity, suggesting a social learning process.

While a lot of effort has gone into distinguishing between learning and imitation, from a policy perspective, this distinction perhaps would not matter substantially. Also, from a practical standpoint it would appear that when making a fundamental decision like adopting a new seed technology, farmers would seek to gather substantial knowledge about the issue, rather than adopt casually based on their neighbors' adoption behaviors. However, on less consequential matters they might be more prone to imitate.

Characteristics of local social structures as well as what neighbors are doing can effect adoption. Rogers (1962) cited three characteristics of social structure that promoted technology adoption by facilitating information flows among members of a community. The three characteristics are: (i) group homogeneity (the degree to which individuals interacting with each other have certain similar attributes, e.g., similar ethnicity); (ii) leadership heterogeneity (when leaders in a community have different social and economic characteristics, and consequently have different communication channels across the community); and (iii) participatory norms (the degree to which communication and decision making within a community are interactive). Isham (2002) considered these as indicators of social capital and found evidence that ethnic affiliations and consultative norms led to increased information sharing and increased technology adoption. His findings were based on the study of social structure's influence, which varied from one village to another, on fertilizer adoption in rural Tanzania.

Studies incorporating social interactions in the form of neighbor effects or social learning have generated tremendous interest in the field of economics. The main focus of economists has been to develop sound microeconomic foundations for their theoretical and empirical analysis.

2.3 Concluding Comments

Early sociology and communications studies, which launched research on technology adoption, focused mainly on the nature of social interactions and communication patterns. Later, economists began studying the adoption process by focusing on the economic factors that affected adoption. Over time, economists incorporated some sociological features in their analyses by studying the roles of communications channels and experimentation. Despite such efforts, these two disciplines have not converged or overlapped in their research objectives. Moreover, while economists, to varying degrees, have incorporated the objectives of early sociology studies, sociologists have moved away from the research approach of their earlier colleagues to pursue different paradigms. This shift in research objectives has contributed to a divergence in the two approaches.

Ruttan (2003, p.182) argues that the focus of adoption studies in sociology moved away "from modernization … toward dependency and other class based perspectives" and the "diffusion of technology became part of the problem rather than the solution." Economists perceived new technologies to be beneficial to the public welfare and as an engine of economic growth while sociologists became more interested in analyzing the consequences of new technologies on income inequality, environmental degradation, and rural communities and culture.[11] The disciplines' failure to converge is perhaps an impediment to a fuller understanding the adoption process. The diverging research approaches potentially provide a broad spectrum of ideas and theories on which to build a multifaceted study of the technology adoption process, involving sociological, economic, geographical, technological, historical, and psychological concerns.

In this dissertation, we try to incorporate sociological phenomenon with economic determinants of adoption by attempting to ascertain how social interactions can potentially influence adoption behavior. Apart from exploring neighbors based on physical proximity, we also explore the concept of neighbors based on socioeconomic proximity. We supplement our empirical observations with findings from fieldwork conducted for the Pakistan study. Our study thus, follows the approach of economists incorporating sociological concerns in their technology adoption analyses.

[11] Lawrence Busch (1978) argued for a Hermeneutic-Dialectic approach to studying technology diffusion and adoption. He called for a deeper understanding of the communications process based on insights from interpretive and post-modernist theory. In his view, instead of focusing on a process of communication based on the narrow concept of "scientific rationality," studies should be more culture sensitive and culture specific.

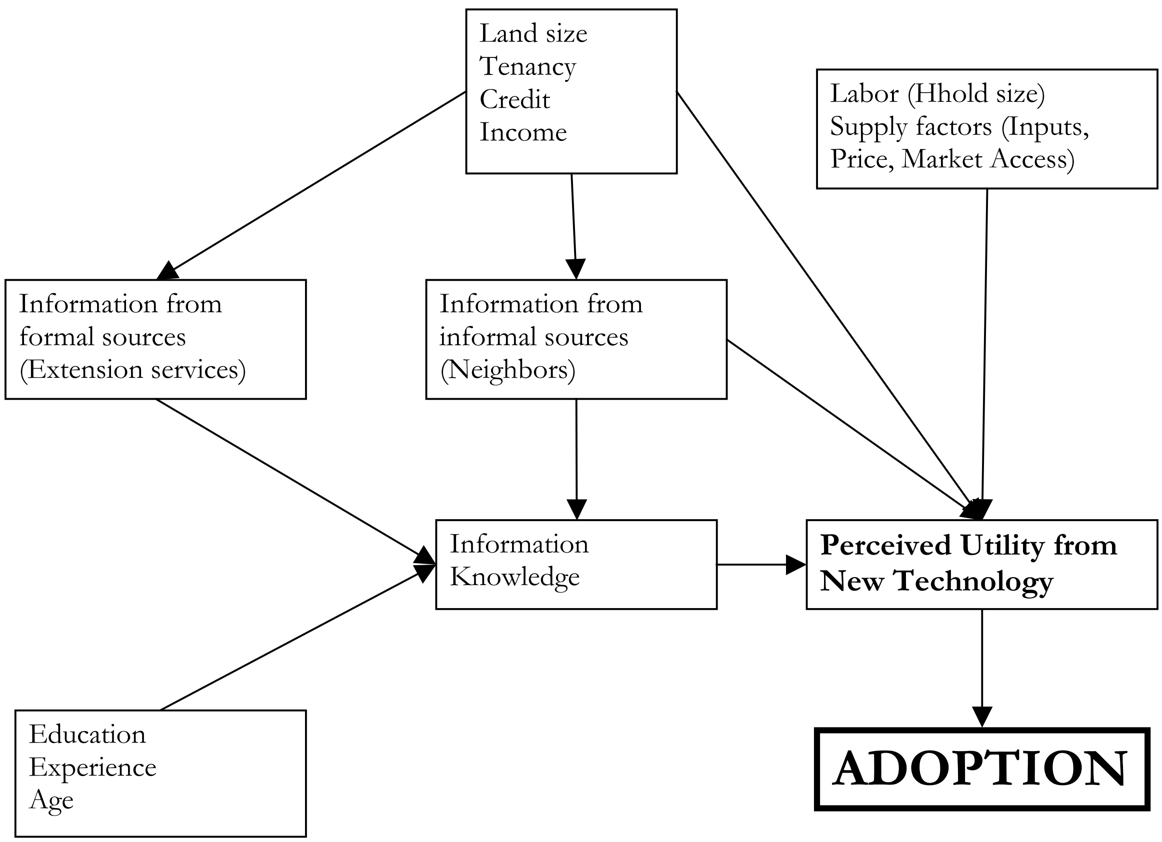
Chapter 3

Conceptual Background

Individuals choose between technologies in a way that maximizes their perceived utilities in terms of economic and social rewards. The adoption of a new technology entails costs of investing in economic resources and acquiring information about the technology. Factors influencing adoption are complex, interrelated and overlapping. They can be broadly categorized into two groups: (i) production or economic constraint related factors and (ii) information related factors. This Chapter discusses the nature and role of production and information related variables on adoption. It also contains an elaborate discussion on motivating the role of neighbors in adoption behavior.

In their adoption decisions, households are constrained by production or endowment factors such as land size, credit access, labor market conditions, tenancy, supply of inputs, price, access to markets and infrastructure facilities. While a farm household may be willing to adopt, if one or more of these constraints are stringent enough, it may not have the ability to adopt. Information related variables influence adoption by affecting individuals' subjective perceptions of the new technology and by mitigating the potential uncertainties that individuals face. Households may obtain information from human capital, experimentation, formal public sources, and informal discussions with family members, friends, and neighbors. Production and information related factors are often interconnected, e.g., individuals with greater access to land may also have higher levels of education or have easier access to public information. We can conceptualize the technology adoption decision as shown in Figure 3.1.

Figure 3.1: Illustration of Adoption Behavior



3.1 Production Related Variables

<u>I. Land Size.</u> New agricultural technologies often involve significant set-up costs and these fixed costs can potentially reduce the tendency of smaller farms to adopt. Early empirical evidence supports this notion (e.g., Weil 1970, Binswanger 1978). Though the adoption of HYV crops are ostensibly scale neutral, even in its case, empirical studies show that land size

tends to positively impact HYV use. This is a likely outcome because fixed costs of adoption can be present in terms of learning, training hired labor, and locating markets. Another reason why larger land holdings may facilitate adoption of new technologies is that credit may be more readily available for larger farms.[12]

II. Credit Constraints. If adoption requires fixed investments, differential access to capital could affect adoption behavior. For instance, the use of capital-intensive technologies like tractors can be costly, as can be inputs such as seeds and fertilizers. In such cases, access to credit markets would facilitate adoption. Household savings and off-farm income are also determinants of capital access and could, in turn, influence adoption behavior.

III. Labor Availability. If a technology is labor-saving, labor shortages would encourage adoption, while if a technology is labor-intensive, like HYV seed technology, labor shortages would impede adoption. The seasonal nature of agricultural production could often lead to labor shortages and households with limited family labor or inadequate access to labor markets might find it less beneficial to adopt a labor-intensive technology. A household with more individuals who are able to work (e.g., individuals between the ages 15-55 years) would be expected to benefit more from adopting a labor-intensive technology. Also, larger households would be more likely to adopt because they are likelier to cultivate land more intensively.

IV. Tenancy. Predictions from the theoretical economics literature regarding the role of tenure arrangements in the adoption decision are ambiguous. In general, it is expected that

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[12] The discussion here concerns the impact of land size on whether a household adopts a new technology or not. The implications of land size are trickier when intensity of use of a new technology (e.g., the fraction of land allocated to a new crop variety) is considered. For a discussion on this issue, see Just and Zilberman (1983).

tenants who have uncertain claims on the lands they cultivate would be reluctant to adopt a technology if it entails significant fixed costs. Tenancy also might influence adoption more indirectly because of its effects on access to credit, inputs, markets, and technical information (Schutjer and Van der Veen 1977). Bell (1972) suggests that the impact of tenancy on adoption would depend on the specific relationship between the owner and the tenant. If a risk averse tenant were to favorably regard the adoption of a particular technology, it was likely that the land owner, being even less risk averse, would find it adoption profitable as well, and would encourage the tenant to adopt by sharing the costs of adoption, if necessary. In such cases, tenants' attitudes toward adoption would depend on the profitability and risk of the new technology. Alternatively, if a land owner and his tenants do not have a cooperative relationship, as is typical with absentee landlords, tenants may lack the capital to adopt.

V. Supply Factors and Price. In the economics literature, factor availability and factor price have traditionally been cited as vital factors in adoption. The availability of complementary inputs is expected to impact adoption because in order for a technology like new seed varieties to be adopted, households would need to have access to relevant fertilizers, irrigation, and other inputs. Also, access to markets and access to infrastructure (e.g., roads and highways) are likely to increase profits from adopting a technology and thus, further encourage adoption.

The price of inputs and outputs, or their ratio, could affect profitability, and thereby affect individuals' adoption behaviors. Kohli and Singh (1997) found that input availability and prices played important roles in HYV seed adoption in Punjab, India. However, limited cross-sectional variability in price ratios often limits their use in household adoption studies (Heisey et al 1993), as is the case in the present study.

3.2 Information Related Variables

I. Human Capital. A higher level of education could enable a greater understanding of the applications of a new technology, thereby encouraging adoption. In the case of agriculture, it is important to note that farming skills are largely dependent on experience and knowledge of agricultural practices and local conditions (e.g., soil and weather conditions) rather than on formal education. As a result, variables such as the length of time one has lived in an area or been involved in agriculture may be positively related to adoption, and education could be less significant. The age of farmers might often serve as an indicator of experience also; however, it could be the case that after a certain threshold age a farmer may become more conservative or risk averse, which would offset the effects of longer farming experience. Age could then have a non-linear effect, and both age and age-squared variables would explain adoption behavior (Heisey et al 1993).

II. Own Experience. Households that have a positive personal experience with an existing technology would be less inclined to adopt a new technology, while negative experiences would encourage them to adopt. Similarly, having adopted a new technology, positive experiences would reinforce its validity to current adopters, while negative experiences would result in reconsideration of the adoption decision.

III. Public Information Sources. Superior access to public sources of information would enable individuals to effectively understand the suitability of a new technology to their specific needs. In the context of agricultural activities, individuals with greater contacts with local agricultural extension offices are likelier to find out about the characteristics of a new technology sooner than individuals with fewer contacts. Frequently, individuals who are in leadership positions in the village or who are politically well-connected become privy to superior information provided by public sources, and have early access to innovations (especially those supplied through government channels).

IV: Informal Sources. Positive experience and enthusiasm for a new technology among an individual's peers would make him/her more inclined to adopt a new technology. This is attributable to the fact that much of the inherent uncertainty regarding adoption would be dispelled by peers' enthusiasm and experiences. Section 3.3 below discusses this issue in further detail.

3.3 Influence of Neighbors

Analyzing the concept of neighbors provides an understanding of how individuals interact, share information, and learn from others in society. What is unique about information obtained through interaction with neighbors is the fact that it embodies externalities (convincing one person to adopt a technology can lead to others adopting as well). If governments are interested in promoting the adoption of a particular technology, it would be useful to know the extent of the positive externality of convincing a farmer to adopt. Governments could then invest resources to persuade farmers to adopt the technology in a way that reflects the externalities associated with such persuasion. Governments could also get a sense of how to time their interventions. Conversely, ignoring neighbor effects could lead to misguided policies. The estimates of the parameters of interest might be biased if neighbor influences are important but are excluded from analysis. For example, if the influence of communication among neighbors is ignored in a particular area that has a high rate of literacy and active communication networks, then the estimated influence of education on technology adoption would be biased upwards. A policy of increasing the literacy levels of farmers to diffuse the technology would then be misguided (Case 1992).

Individuals may share information with not only those who are in close geographical proximity but also with those who have similar attributes, e.g., individuals with common ethnicity, age, language, or religion. If individuals do communicate with others and are influenced by them, adoption (or non-adoption) would be clustered across geographical space or across some socioeconomic reference space.[13] These modes of spatial interaction are discussed below.

I. Physical neighbors. Individual interactions remain highly localized in rural areas in developing countries where transportation and telecommunication networks are poor. Since developing and sustaining social relationships have pecuniary and time costs, individuals are likelier to communicate more effectively with those who are located physically closer to them.[14] Local level social venues and organizations, such as markets, clubs, and places of worship tend to promote interaction and information sharing among individuals. In agriculture especially, local conditions are often highly relevant to the efficacy of new

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[13] Banerjee (1992, p. 798) developed a model of imitative behavior in which "paying heed to what everyone else is doing is rational because their decisions may reflect information that they have and we do not." His model makes even a stronger point (p.798): " . . . a likely consequence of people trying to use this information is what we call *herd behavior* – everyone doing what everyone else is doing, even when their private information suggests doing something quite different."

[14] Sociologists have debated the diminishing role of local interactions in developed economies. Even in such economies, local level interaction appears strong despite the vast improvements in long-distance communication methods and high levels of individual mobility. See, for example, Wellman (1996), Conley and Topa (2002). In his study of inhabitants of Toronto during the 1980s, Wellman (1996) found that as much as 64 percent of all contacts took place between individuals who lived less than five miles apart from each other.

technologies, and individuals tend to be strongly influenced by their local interactions. Physical proximity among individuals can be measured by physical distance or by travel time. Individuals could also be considered neighbors if they live within a certain geographical entity like a village. This is the most commonly used metric of neighbors in adoption studies (e.g., Case 1992, Foster and Rosenzweig 1995, Pomp and Burger 1995, Munshi 2004).

II. Socioeconomic neighbors. Among people in close physical proximity, an individual would likely have more meaningful communication with those who are more alike to him. Individuals tend to base their social networks around others who are very similar to themselves in terms of socioeconomic and demographic attributes. Individuals relate to each other based on characteristics such as ethnicity, religion, caste, age, gender, educational level, and occupation. Sociologists refer to this phenomenon as *homophily* (Rogers 1962), while economists refer to it as *assortative matching* (Ghatak 1999). An interesting theoretical paper by Akerlof (1997) models social interactions based on the *social distance* among agents. Esteban and Ray (1994) define groups or associations as having three main characteristics: a high degree of homogeneity within a group; a high degree of heterogeneity across groups; and significant size.

Empirical studies have found evidence of individual networks based on characteristics such as ethnicity, religion, and education. For example, Conley and Topa's (2002) study of unemployment in Chicago between 1980 and 1990 found evidence of individual networks based on ethnicity and occupation. Some technology adoption studies have also explored similar concepts. In their study of contraceptive use in rural Bangladesh, Munshi and Myaux (2005) found evidence of significant social interactions among women belonging to similar religious groups. As was mentioned in the previous chapter, Romani

(2002) defined neighbors along ethnic lines, while Bandiera and Rasul (2004) explored social interaction along religion lines. In our Pakistan study, we define neighbors on the basis of land ownership since it is an indicator of economic and social status. We find evidence that in Pakistan, economic and social status, as captured by differential land holdings, determine how individuals interact with each other.

Manski (1993) cautions that in order to accurately measure social interaction effects, socioeconomic reference groups must be clearly defined and be *at least partially* observable to the econometrician (Conley and Topa 2002). The definition of neighbors must be solidly based on ground realities and on theory. Estimating social interactions is challenging since direct data on communication, such as individuals who are within the same communication network and the nature of their conversations, are usually not available. As a result, certain simplifying assumptions need to me made for empirical work. A common practice is to use village aggregates (e.g., cumulative adoption) to proxy for information sources (Foster and Rosenzweig 1995; Munshi 2004). A majority of adoption studies consider the village to be the unit of social interaction and assumes that every household is aware of the decisions and actions of all other households within the village. Conley and Udry (2001, p.668) agree that " … these assumptions are [not] literally true, but they seem to be a reasonable starting point for a discussion." However, in their study of fertilizer use by pineapple farmers in Ghana, they found strong contradictions to these assumptions. They found that farmers learn from only a small fraction of farmers in a village, and when they do learn from others, they gain *relative* rather than *complete* information. For their subsequent study on social learning, Udry and Conley (2003) collected detailed data on information exchange among farmers instead of relying on village level aggregate variables.

This present study uses village level aggregates to proxy for neighbor influence variables. While this is done mainly to address data constraints, it also seems plausible that village level averages should provide a reasonable estimate of the activities in an individual's actual neighborhood. When a farmer is deciding whether to adopt a new seed technology, he considers various issues in his environment, such as his neighbors' crop choices, the quality of their harvests (i.e., if they had better or worse harvest than he did), and the soil quality of other farmers' lands. Our fieldwork in Pakistan suggests that farmers are quite knowledgeable about these issues.[15]

3.4 Dynamics and Nature of the Influence of Neighbors: Some Hypotheses

On the basis of the discussion on neighbors and the role of information in technology adoption we can propose a set of hypotheses concerning the influence of neighbors on adoption:

Proposition 1: Individuals with more neighbors adopting a new technology would have more information on the new technology and would be likelier to adopt.

Proposition 2: The influence of neighbors on individuals is heterogeneous. Neighbors would matter less for individuals with greater human capital and better access to public information, than for individuals with poorer human capital and limited access to public information.

Proposition 3: Individuals gain more information from (and hence are more influenced by) people within their reference group than by people in other reference groups.

Proposition 4: Individuals are likely to be influenced not just by the actions of their neighbors but by the outcomes of their neighbors' actions as well.

[15] The decision to adopt a new seed technology is perhaps a less sophisticated decision than Udry and Conley's (2003) study on farmers' decisions of how much fertilizer to use based on the amount of fertilizer used by neighbors. As such, the level of neighbor related information that farmers need or use is not as detailed.

Greater familiarity with neighbors' experiences with a new technology would reduce an individual's perceptions of uncertainty and encourage him to adopt, as stated in Proposition 1. Proposition 2 states that individuals are impacted differently by their neighbors (Rogers 1962). Individuals with more precise information, whether through higher education levels, personal experience with a technology, or through access to reliable public information sources, would rely less on neighbors than their less informed counterparts. Proposition 3 states that if neighbors were stratified along socioeconomic or demographic attributes, individuals would garner more information from those within their own reference groups rather than from those across their reference groups. It is natural for less informed individuals to seek out information from more informed individuals, but if the better informed individuals belong to separate groups, they are less likely to communicate with them and be influenced by them. If, however, boundaries based on socioeconomic and cultural traits are less rigid, there would be communication across reference groups as well. Finally, individuals do not simply observe their neighbors decisions regarding adoption; they also observe how neighbors performed given their adoption decisions. As such, neighbors' positive experiences with adoption would encourage non-adopters to adopt, while their relatively negative experiences would tend to discourage adoption. Sociological studies take this last argument (Proposition 4) further and claim that successful adopters influence their neighbors more than do unsuccessful adopters (e.g., Rogers 1962). While this claim describes a behavioral issue and is not based on solid microfoundations, studies in economics have found evidence of this (e.g., Zhang et al 2002). In the following two chapters, we empirically evaluate these four propositions and discuss their implications.

Chapter 4

New High Yield Variety (HYV) Wheat Adoption in Pakistan

High Yield Variety (HYV) wheat seeds were introduced in Pakistan in the mid to late 1960s and within a few years these seeds were widely adopted, replacing the traditional wheat seeds. While farmers were initially quick to switch to HYV seeds, subsequently they were more reluctant to switch to new varieties of HYV seeds as they became available, continuing to use older varieties of HYV seeds instead. This chapter focuses on the adoption of new HYV wheat seeds in Pakistan.

The chapter is divided into four sections. The first section, Section 4.1, discusses the context within which the study takes place and describes the nature of the new seed technology. It elaborates on the problem of slow adoption of new HYV seeds, focusing on informational and institutional barriers that possibly hindered adoption. An important focus of the chapter is to examine the role of neighbors in the adoption process. To analyze neighbors' influence in the adoption decision, we develop the concept of neighbors based on land ownership among Pakistani households. We used this as the defining criterion because it was apparent that in rural Pakistan farmers tended to interact with each other based on relative social and economic status, land ownership being an indicator of both. Section 4.2 introduces the sample and the data used for the study and develops the empirical methodology of the study. Descriptive statistics of adoption dynamics are detailed in this section also. Section 4.3 discusses the estimation results and their implications. Results show that information barriers were consequential in the adoption decisions of farmers, and neighbors played an important role in the adoption process. Furthermore, our concept of socioeconomic neighbors, as defined by household land ownership, seemed to be an appropriate concept of social interaction in rural Pakistan. The last section of the chapter provides a brief summary of our findings.

4.1 Context

4.1.1 Varietal Adoption Over Time in Pakistan

Agriculture is a mainstay of Pakistan's economy, accounting for almost a fourth of the economy, wheat being its most important crop. Wheat accounted for almost 40 percent of the total cropped area in the country and represented 75 percent of total food grain production during 1999-2000 (Iqbal et al 2002). Despite the widespread production of wheat, Pakistan imports wheat quite frequently as domestic production often falls short of demand. For example, during 1998-1999, the country produced 18 million tons of wheat and imported 2 million tons (Farooq and Iqbal 2000). Although Pakistan does not face chronic wheat shortages, food security is a major preoccupation of policymakers.

A sizable body of literature has focused on High Yield Variety (HYV) seeds that led the Green Revolution in rice and wheat and often cited it as a solution to the threat of food shortages in South Asia and the developing world. A smaller portion of literature has recently focused on adoption dynamics during the post-Green Revolution phase. Byerlee (1996) classifies seed variety changes into two broad categories. *Type A* changes occurred when the first HYV seeds replaced the traditional varieties (TVs) or older improved varieties, dramatically shifting agricultural productivity (also referred to as the Green Revolution). *Type B* changes occur when new vintages of HYV are introduced (at least once a decade) to replace older vintages of HYV (this is referred to as the post-Green Evolution period). Type B changes, which are usually "evolutionary rather than revolutionary" (Byerlee 1996), are not as dramatic as the Type A changes. Differences between new and older HYV seeds are subtler than the drastic difference between the original HYV seeds and the traditional varieties that they replaced. This chapter focuses on new HYV wheat seed adoption in Pakistan during 1986-1989, the post-Green Revolution period, i.e., Type B changes.

In Pakistan the Green Revolution period is considered to have begun in 1967 when a semi-dwarf wheat variety named *Maxipak* began to be widely adopted replacing the traditional wheat varieties. The plant had a sturdier stalk than the traditional varieties, and produced multiple stalks from its base, allowing more heads of wheat per plant. Developed in Mexico by researchers at the International Maize and Wheat Improvement Center (CIMMYT), Maxipak was an early maturing seed variety that possessed superior genetics, was widely adaptable, and had better disease resistance than the traditional varieties. The average annual increase in wheat yield during in the pre-Green Revolution period in Pakistan (1947-1966) was a mere 0.23 percent, whereas during the Green Revolution period (1967-1986), Pakistan's wheat yield increased by 2.7 percent per year (Farooq and Iqbal 2000). Apart from larger yields, the introduction of Maxipak and other HYV seeds also marked a dramatic shift from traditional farming practices in Pakistan, including the widespread diffusion of fertilizer and irrigation facilities, and more intensive use of labor.

The end of the Green Revolution period in Pakistan is considered to be around 1986 with the consolidation of HYV wheat use. By 1986, 90 percent of farmers had switched from traditional varieties to HYVs (Byerlee 1987). Proliferating first in well-irrigated areas, the seeds eventually spread to rain-fed areas as well. As agriculture transitioned into the post-Green Revolution period, the critical decisions facing farmers was selecting between newer and older vintages of HYVs. The newer HYVs were fertilizer responsive and semi-dwarf wheats like the older HYVs, and thus did not require changes in input use or farming techniques. They possessed superior yield potential than older HYVs, although the differences were not as marked as the differences between HYVs and traditional wheat varieties. In the post-Green Revolution period (1987-998), annual wheat yield grew at around 1.9 percent, a reasonably high growth rate, but lower than the Green Revolution period growth (Farooq and Iqbal 2000).

While farmers in Pakistan switched from traditional varieties to HYVs rather rapidly during the Green Revolution, they have been slow to switch from old HYVs to newer HYVs. Slow varietal replacement has kept the actual wheat yield lower than the potential yield. Varietal replacement in Pakistan is slow when compared with other similar wheat producing areas such as India's Punjab province and Northwestern Mexico's Yaqui Valley. For example, in Pakistan's Punjab province, the average age of semi-dwarf varieties of wheat is almost nine years, whereas in neighboring India's Punjab province it is 6.5 years and in Mexico's Yaqui Valley, it is only four years (Heisey et al 1993).

It is desirable for farmers to switch to newer HYVs because genetic disease-resistance of all varieties breaks down within a few years and they become vulnerable to leaf and stripe rust. The rust pathogen evolves constantly, and within a few years of cultivation, new seed varieties become susceptible to new strains of the pathogen. Heisey et al (1993) points out that HYVs in circulation for roughly ten years in Pakistan, was resistant to rust for an average of only 6.3 years. Continuing use of old varieties increases the likelihood of a major rust epidemic leading to severe economic losses. Heisey et al (1993) cited a Pakistan

Agricultural Research Council (PARC) survey study that estimated the economic losses from planting rust-susceptible varieties during 1986-87, a non-epidemic year, at roughly US$40-50 million. During 1977-78, when the Punjab province suffered a major rust epidemic, the losses were at least $117 million above the typical losses in years without epidemics.

Heisey (1990) found that Pakistani farmers pay attention to relative yield characteristics in their decision to adopt a new HYV seed. Even if the new variety had superior disease resistance, a certain perceived "threshold" increase in yield was often necessary to prod farmers to adopt. One likely reason for the slow adoption of new HYVs was that, from a farmer's perspective, the yield increases were not substantial enough. Another reason for slow adoption was the farmers' inadequate knowledge regarding the risk to yields due to disease. Farmers did not seem to fully grasp the seriousness of disease risks of older varieties (Heisey 1990). Fieldwork conducted for this present study is supportive of this insight.[16] Other characteristics that could likely influence farmers' decision to adopt a new variety were *chapati* (baking) quality, *bhusa* (straw) yield (for domestic animal consumption), late planting suitability, and land preparation and fertilizer use requirements. Since the new varieties were also semi-dwarf like the old HYV varieties, these characteristics were not significantly different between varieties. While these considerations did influence the adoption of HYVs over traditional varieties to varying degrees, they were unlikely to substantially influence adoption decisions between older and new HYV varieties.

[16] From conversation with farmers in villages in Attock and Faisalabad in 2004, it appears that farmers do not feel that the risk of disease is very high for old variety crops. Village level agricultural extension officers claimed that most farmers did not pay much heed to their warnings about disease risk of old varieties.

4.1.2 HYV Seed Development and Farmers' Sources of Seeds

Since the introduction of *Maxipak* in 1965, over 80 wheat varieties have been introduced in Pakistan, of which only 25 have been commercially adopted. The diffusion of individual HYV seeds was largely region-specific and depended on suitability to local growing conditions, but a few multi-regional varieties also prospered. Beginning the mid 1960s the government took a lead role in seed development and distribution. Most varieties were developed domestically at government research institutes, with occasional collaboration with CIMMYT. Provincial level public seed authorities produced seed and then marketed it through public outlets and through private dealers. The seed authorities, however, were conservative in their approach to seed multiplication because they were unsure which varieties farmers would respond to. As a result, at the beginning of the wheat season, seed authorities asked their public and private dealers to gauge the anticipated demand for seeds, and they supplied them with seeds accordingly. Thus, instead of taking a lead role in promoting the adoption of newer HYV seeds, the seed authorities merely supplied seeds based on anticipated use. Poor planning and coordination between the seed authorities and the dealers often led to shortages or oversupply of certain types of seed (Heisey 1990).

The dynamics of farmers' seed use are very important to the adoption process. Since wheat is a self-pollinating crop, its seed can be saved by farmers and used in subsequent years. Farmers mostly planted seeds that they had retained from a previous year's crop. They also exchanged seeds with each other, often of the same variety, since they considered the continual use of the same seeds on the same plot of land to be detrimental to the harvest. Farmers usually bought seeds from the market only when they were adopting a new variety. Alternatively, they got new varieties from other neighboring farmers who had already adopted them. Thus, exchange with neighbors was not only of information, but of seeds as well. Heisey (1990) estimated that between 20 to 30 percent of farmers used seeds they got from other farmers, while only about 10 percent bought seeds from a seed depot. The remaining 60 percent of farmers used seeds left over from previous crop cycles. They also found that when farmers were using a seed for the first time, in about half the cases, geographic neighbors were their sources for the new seed. The exchange of seeds among farmers tended to be highly localized, with about 80 percent of farmers procuring seeds from others living within a five-kilometer radius. Farmers who acquired seeds from depots tended to be larger landholders, who, in subsequent years, also supplied seeds to neighboring farmers. Iqbal et al (2002) noted that most farmers in Pakistan bought or exchanged small amounts of new wheat seeds and multiplied it on their own farms for use in ensuing years. As a result, farmers typically did not use large amounts of cash or credit to buy new seeds.

Local-level informal exchange of seeds among farmers was an important means of technology diffusion in the early stages of the Green Revolution (Lowdermilk 1972). Likewise, in the post-Green Revolution era, the informal exchange of seeds among local farmers continued to be an important factor, partly due to the failure of seed and information delivery by public institutions such as seed developers, seed distributors, and agricultural extension workers.

4.1.3 Information Problems and Formal Sources of Information

Formal sources of information available to farmers have traditionally been extremely weak in Pakistan. In the absence of accessible formal sources of information, farmers were more likely to rely on each other as credible sources of information. While informal information exchange among neighbors has been strong, poor education and lack of access to reliable public sources of information have hampered farmers from learning about productive agricultural practices in a timely manner, often resulting in the persistence of relatively unsound agricultural practices. Even though formal sources of information were scarce during the Green Revolution, the use of HYV seeds spread rapidly because of the evidence of overwhelming yield advantages (Lowdermilk, 1972). However, in the post-Green Revolution era, the distinction between the old and the new HYV seed technologies was less obvious. As a result, in the face of inadequate and unreliable formal information sources, farmers took longer to decipher the nuances of a new technology, be it through their own experience or through neighbors' actions and experiences.

Information available to farmers has often appeared incomplete and flawed to analysts. For example, Heisey (1990) observed that a majority of farmers considered the relative yield advantages of the new HYVs to be the main determining factor in adoption. Instead, had farmers placed more weight on the risks associated with the susceptibility of older HYV varieties to disease, they would have been likelier to switch to the new HYV seeds sooner. Heisey (1990) reported that while farmers were aware of major diseases such as rust that could severely damage their crop yields, most of them were not too worried about such risks, and in fact, very few farmers thought a rust epidemic of the scale of 1977 to be probable. Based on their survey of farmers in the province of Punjab in Pakistan, Heisey (1990, p.67) state: "Farmers' awareness of rust as a major problem would probably be much greater in a year immediately following an epidemic. … But in a relatively normal year some years after farmers have experienced serious losses from rust, the threat of disease by itself is unlikely to motivate farmers to change varieties, given the current state of their knowledge about varietal rust resistance and rust epidemics." Farmers appear to heavily discount the past and base their decisions to adopt a new seed variety on more currently observable or tangible characteristics of the seeds.

Formal sources of information can play a very important role in the transmission of information regarding the more intangible and unobservable characteristics of a technology. In principal, formal information sources such as agricultural extension offices could play this role, especially in bringing information to the less educated and poorer farmers who have less access to formal information. In practice, however, the majority of farmers in Pakistan did not have any meaningful contact with agricultural extension offices (Faruqee 1995, Iqbal et al 2002). Often, a lack of adequate training and motivation hindered extensions workers' task of improving farmers' knowledge and efficiency. Extension workers with higher education and better communications skills, who could have provided better outreach support to farmers, were frequently assigned administrative jobs (Faruqee 1995). Feedback from farmers was also poor, and in general, extension workers were not sufficiently knowledgeable about farmers' habits, struggles, and needs. Another criticism ascribed to agricultural extension officers was that their services were slanted toward serving the landed and wealthier farmers; the smaller landholders and poorer farmers had far less access to extension workers (Byerlee 1994, Husain et al 1994). A survey conducted in 1986 by Byerlee (1994) in Punjab showed that 60 percent of farmers with above 25 acres of land had contact with extension services the previous year, while only 24 percent of farmers with 12.5 to 25 acres of land had contact with extension workers.

4.1.4 Informal Information Sources: Concept of Neighbors in Pakistan

In Pakistan, while formal sources of information were largely ineffectual, informal information exchange thrived. Neighboring farmers were an important source of information regarding the newly introduced HYV seeds at the onset of the Green Revolution in Pakistan (Lowdermilk 1972), and continued to be an important source in the Post-Green Revolution period as well. In the survey conducted by Heisey (1990), over half of the farmers in Punjab said that neighboring farmers were their main source of information about agricultural practices. These studies defined neighboring farmers as farmers living within the same village. Fieldwork for the present study also indicated that farmers appeared to observe and learn from their neighbors' adoption experiences. In addition, fieldwork also revealed that many farmers got new HYV seeds from neighboring farmers rather than going to the market and purchasing them. The combined effect of information and seed exchange made neighbors an important parameter in technology diffusion.[17]

The present study uses a geographical concept of neighbors as a starting point to examine how farmers are influenced by what others in their village are thinking and doing regarding new HYV wheat adoption. However, the main thrust of this study is to create indicators of *socio-economic distance* and study their effect on inter-personal exchange with respect to HYV adoption behavior. Although individuals are likely to communicate with those situated close to them in space, they are most likely to communicate with those who they consider their 'peers', and there may be important socioeconomic dimensions to peer

[17] Existing technology adoption studies on neighbors' influences have focused on the role of learning and information exchange (e.g., Case 1992, Foster and Rosenzweig 1995, Munshi 2004); they do not deliberate on seed exchange as a part of neighbors' influence.

networks. In rural Pakistan, land ownership is linked to both economic well-being and social standing, and therefore, we explore inter-personal exchange regarding adoption along land ownership lines.

The use of land groups as a criterion to define neighborhoods or peer networks is based on fieldwork findings. Our direct observations in rural Pakistan suggested that while farmers communicate with others around them, they are more inclined to interact and communicate with those having similar landholdings. Consequently, for the empirical analysis of this study, we classify households with similar landholdings to be each other's neighbors. Households may well interact across land groups, but more substantial interaction is expected to take place within groups.

To be certain, in rural Pakistan individuals tend to identify with one another most often along kinship or clan lines, commonly referred to as *zaat* or *birathri* (Lyon 2002). Data on this potentially interesting neighborhood metric is unavailable in the panel survey of wheat farming practices used for this study. Moreover, Carraro et al (2004) argued that given the high number of zaats or birathris within villages, it is very difficult to classify them into statistically informative groups.[18] Of course, the concept of birathri is extremely important in social decisions such as marriage, but anecdotal evidence suggests that regarding agricultural practices, individuals are less likely to limit their interactions to such a narrow group. Though this concept is attractive, we do not consider it in this study. Another socioeconomic concept that could have been considered as a neighborhood metric is household income. However, income is typically poorly measured in rural survey data

[18] Of the 4,000 households interviewed by Carraro et al (2004), there were 600 different birathris. These birathris could, however, be classified into low, medium and high status groups.

(Deaton 1997), and there exists a very strong correlation between farm income and land ownership in rural Pakistan (Alderman and Garcia 1993).[19] Household surveys from this region indicate that the poor own significantly less land than the non-poor (Malik 2003), and land ownership is therefore a sensible neighborhood criterion.

4.1.5 Neighbors Based on Land Groups

To validate the use of land size to categorize farming households into different neighborhoods, substantial interactions between households with similar land sizes must be established. Existing evidence on this topic is rather sparse, and this study relies heavily on anecdotal evidence gathered from fieldwork to substantiate the use of land as a neighborhood criterion.

In a country like Pakistan, the importance of land goes beyond its role in agricultural production. Apart from being an asset that is used for savings, as a hedge against inflation, and as collateral for credit, land is also an important source of power and prestige (Heltberg 1998). According to the Pakistan Participatory Poverty Assessment (2002), land ownership was the most important source of power in most of the areas studied. Farmers with larger landholdings tend to be more economically solvent, have higher social standing, and possess more political power. As such, these farmers dominate local decision-making processes and social relations. Carraro et al (2004) claimed that land access and distribution are vital factors in determining social structure in rural Pakistan. By contrasting the social status of landed and landless farmers, they argued that landowners are unmistakably privileged,

[19] Land is also a more reliable indicator of economic well-being, because unlike income which can fluctuate from year to year quite sharply, land ownership remains more or less stable.

exercising broad influence over rural institutions, especially credit and labor markets, while the landless face varying degrees of "social exclusion." The influence of land ownership on social structure is perhaps more severe due to Pakistan's highly unequal distribution of land. Nationwide, the Gini coefficient of owned land is around 0.6 (Malik 2005). The top 7 percent of farms (sized above 25 acres) accounted for 40 percent of the farm area, while farms sized above 150 acres, which were only 0.3 percent of all farms, occupied 10 percent of total farm area. In stark contrast, the bottom 25 percent of farms (sized below 2.5 acres) accounted for only 4 percent of farm area (Malik 2005).

The discussion in this chapter has so far stressed the connection between land ownership and social status and provides plausible inferences about how farmers interact with each other along land groups. For example, we can infer that households with large landholdings are more akin to other households with such large land holdings, and accordingly, would be expected to interact and communicate more with each other. This explanation still, however, does not provide explicit evidence that farmers share *meaningful* and *substantial* information regarding HYV wheat seeds with one another within similar land groups, or that they exchange seeds within similar land groups. Information gathered during a six-week fieldwork trip is supportive of such a claim. Part of the fieldwork consisted of qualitative open-ended interviews with farmers in some of the villages where the IFPRI panel survey was conducted. Given that the data was collected fifteen years ago and household names in the sample were unavailable to us, we could not talk to the sample households. Instead, we talked at length to wheat farmers in a few of the sample villages to ascertain their communication patterns and seed use habits. We also conducted a few focus group discussions with some groups comprised of farmers from different socioeconomic groups (larger and smaller landholders) and others comprising of farmers from similar socioeconomic groups only.[20]

Interviews with farmers indicated that they tended to be more comfortable when interacting with those more like them in terms of land holdings and they were more trusting of the suitability of agricultural information provided by their social peers. Farmers shared information with each other informally in numerous venues: when they were working in the fields, when they would meet in the local teashops or the local community center, when they would come to buy or sell goods in the local markets. This type of informal interaction largely took place among farmers who had similar land holdings (predominantly small landholders). Farmers also found out about the actions and experiences of those whom they did not personally know by word of mouth.

Farmers with larger land holdings invariably had better access to information and technology through local administrative officials and agricultural extension. They could easily travel to meet these officials and had the confidence to approach them to obtain information. In addition, officials were more willing to provide help to large landholders. Having greater access to information sources, large landholding farmers appeared to be less concerned with their neighbors' farming decisions, and were more likely to adopt independently. Conversely, farmers with small landholdings seemed to be more concerned about what others in their surrounding area were doing and how others had fared. These farmers also appeared to be more risk averse regarding technology adoption than farmers with larger landholdings. In an interview one small landholder revealed that he did not have the *himmat* (courage) to adopt for fear of failure.

[20] The nature of the focus groups is described in Appendix A.

Information exchange was not limited to only within land-holding groups. Smaller landholders sought information from wealthier large landholders who tended to be better informed. However, due to the hierarchical nature of the relationship, communication was not very fluid; even though small landholders could to a certain degree observe what larger landholders were doing and could obtain information from them, they were often reluctant to act similarly because they were unsure of the suitability and applicability of large landholders' decisions to their situation. For example, in the district of Faisalabad one small landholder with less than five acres of land told us that he occasionally sought information from large landholders, though he was cautious in accepting their recommendations because "those landed people don't know my capabilities and needs." In contrast, a farmer in Attock with around 25 acres of land (a relatively large landholder) claimed that he was friends with everyone in the village and gave advice to others regarding agricultural practices, but complained that the smaller landholders were uneducated and while they listened to his advice they never followed it. The hierarchical social relationship between larger and smaller landholders was all too evident in the focus group discussions. The relatively wealthier, larger landholders were clearly more confident and dominated the discussions, while the smaller landholders were more reticent. However, when focus groups contained only small landholders, they were much more confident and forthcoming about discussing their agricultural practices and preferences.

Apart from considering their neighbors' actions, farmers also appeared to be concerned about the resultant harvests of other farmers. Information about farmers who had strong harvests or particularly bad harvests appeared to travel far, as farmers tried to understand the causes of their neighbors' successful or failed harvests (i.e., they tried to deduce whether the quality of a harvest was attributable to the type of seeds used, soil quality, land preparation, appropriate fertilizer use, etc.). If neighboring adopters had largely successful harvests, other farmers were likelier to adopt those seeds. Meanwhile, if adopters had been unsuccessful, it adversely influenced the decisions of potential adopters. As much as possible, farmers tried to gauge how other farmers in their similar situations had acted and fared, and land size was hardly the only attribute farmers considered while searching for similarity. For example, farmers were generally cognizant of the soil quality of their neighbors and took this factor into account while judging neighboring farmers' actions and advice. A farmer having land with poor soil quality was unlikely to be convinced by the positive experience of a farmer with better soil quality; however, he would be more influenced by the positive experiences of a farmer with similar soil quality.

In addition to information sharing, an important part of interpersonal exchange among farmers was procuring seeds from or exchanging seeds with one another. Fieldwork experience suggests that seed exchange patterns were quite similar to information exchange patterns, with a majority of exchanges taking place among farmers belonging to similar landholding groups. However, regarding seed exchange, larger landholders had a limited yet distinctive role. In the province of Punjab, larger landholders who were generally the first to buy new seed varieties from the seed depot, also became a source of seed for other farmers. They were usually one of the main sources of seed for the *early* adopters among small landholders (Heisey 1990). Small landholders adopting later mainly tended to get seeds from early small landholding adopters, while large landholders adopting belatedly often bought seeds from the seed depot or from fellow large landholders. Fieldwork confirmed that these seed exchange patterns were particularly relevant to villages in the Punjab province where wheat was the main crop. In Badin and Dir, where wheat was of secondary importance, large landholders were no more likely than small landholders to adopt early and therefore, they usually were not sources of seed for early adopters.

The process of social learning and interpersonal exchange of seeds discussed above potentially slows down adoption. Instead of relying on their own education and information from formal sources, farmers tried to gauge the suitability of new technologies from the actions and experiences of others around them. This process plausibly took more time than if there had been better sources of formal information or more direct sources of acquiring seed.

4.2 Empirical Analysis

4.2.1 Data and Sample Design

The data used in this study comes from a household level panel survey conducted by the International Food Policy Research Institute (IFPRI) between 1986 and 1991.[21] The original aim of the survey was to provide information and policy suggestions to Pakistan's Ministry of Food and Agriculture to support its goal of poverty alleviation. Thus, the survey

[21] A CD-ROM of the dataset can be obtained directly from IFPRI's website by requesting for it at http://www.ifpri.org/data/pakistan01.htm. This dataset has been used quite extensively for academic research. Below is a list of five widely cited academic papers that have been written using the present dataset:

1. Adams, Richard H. 1995. Agricultural Income, Cash Crops and Inequality in Rural Pakistan. *Economic Development and Cultural Change* 43, no. 3: 467-491.
2. Alderman, Harold and Marito Garcia. 1994. Food Security and Health Security: Explaining the Levels of Nutritional Status in Pakistan. *Economic Development and Cultural Change* 42, no. 3: 485-507.
3. Battese, George E., Sohail J. Malik, and Manzoor A. Gill. 1996. An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan. *Journal of Agricultural Economics* 47, no. 1: 37-49.
4. Behrman, Jere R., Andrew D. Foster and Mark Rosenzweig. 1997. The Dynamics of Agricultural Production and the Calorie-Income Relationship: Evidence from Pakistan. *Journal of Econometrics* 77, no. 1: 187-207.
5. Fafchamps, Mercel and Agnes R. Quisumbing. 2003. Social Roles, Human Capital, and the Intrahousehold Division of Labor: Evidence from Pakistan. *Oxford Economic Papers* 55, no. 1: 36-80.

was not designed to be representative of the rural population as a whole, and households living in poorer areas were over-sampled. Approximately 800 rural households, roughly half of which were wheat producing, were interviewed in 14 rounds over five years. Data were collected on technology adoption and farming practices of wheat farmers for the *Rabi* crop seasons of 1986-87, 1987-88 and 1988-89, which correspond to rounds 5, 8 and 11 in the dataset. Wheat is planted between November and December and harvested in March or April. The dry winter season from November to April is called the Rabi season and the crops cultivated in this season are called Rabi crops. The dataset has 2,424 household-round observations from rounds 5, 8 and 11. We drop 1,205 of these observations because those households do not grow wheat, and drop another additional 79 observations for which the type of wheat grown is not identifiable or the data is incomplete or unreliable.[22] Overall, we are left with an unbalanced panel of 1,140 observations for wheat producing households for three crop years, with each year having 417, 355, and 368 households, respectively.

IFPRI selected the survey sample by using production and infrastructure indices to identify the poorest districts in three Pakistani provinces (Punjab, Sindh, Northwest Frontier Province (NWFP)). The districts Badin in Sindh, Attock in Punjab, and Dir in NWFP were selected. Additionally, Faisalabad, a relatively well-off district in Punjab, was also selected to provide some contrast to the poorer districts.[23] The villages and households within the four districts (Attock, Faisalabad, Badin and Dir) were selected using stratified random sampling. Within each district two large wholesale markets or *mandis* were randomly chosen. Villages

[22] The dataset also provides adoption information on households from the Rabi season of 1990-91, but we omit this because it includes information only for households in Punjab and because we do not observe adoption behavior in the preceding Rabi season of 1989-90.
[23] Another district Kalat, in the province of Baluchistan, was selected but subsequently dropped because of logistical problems in carrying out fieldwork.

were stratified into three groups depending on their distance from the mandis: less than five kilometers, between five and ten kilometers, and between ten and twelve kilometers. From these strata, villages were chosen randomly. In all, 45 villages were sampled: six in Faisalabad, eight in Attock, nineteen in Badin, and twelve in Dir. List of households' names were drawn up for each village and survey households were randomly selected from this list. An important feature of the data is that it is possible to construct village level aggregates using sampling weights that characterize the residents of the village, thus enabling measurement of village level effects.

Of the overall 1,140 household observations, 261 were from Faisalabad, 361 from Attock, 191 from Badin and 327 from Dir. The number of households for which at least one observation was obtained in all three crop years was 516 (108 in Faisalabad, 141 in Attock, 124 in Badin, 143 in Dir).

4.2.2 Empirical Model

We analyze the determinants of adopting new HYV wheat, where adoption is defined in binary terms: farmers "adopt" when they are observed to grow any amount of the new HYV variety.[24] We use a discrete choice econometric model of the binary adoption decision, which is based on an underlying random utility model. Rahm and Huffman (1984)

[24] Adoption need not simply be a case of choosing among different options. Farm households might use a new technology and an old one simultaneously. For example, a farm household might allocate separate tracts of land to both old and new HYV seeds. In that case a greater fraction of available land allocated to a new technology would signify a higher *rate* of adoption. This paper, as like most adoption studies, considers adoption as a choice between two exclusive options, since we don't have continuous data on rates of adoption. This is a reasonable specification for Pakistan, since a large number of farmers practice mono-varietal cultivation of wheat. In the Iqbal et al (2002) study, 80 percent farmers are reported to plant only one wheat variety. We observed during our fieldwork that since many farmers are small landholders they tend to grow a single variety only.

analyzed a farm household's adoption decision as a utility maximization problem, where the decision to adopt a particular technology was dependent on the comparison of its net marginal benefits over other options.

A wheat producing household would adopt the new HYV seed if the expected profits from adoption are higher than from continuing the use of the old seed variety. In other words, household i belonging to land group G in village V district D at time t would adopt the new seed variety if its perceived opportunity cost or net benefits from adoption $Y_{iGVDt}*$ are positive. Since a household is likely to be influenced by (e.g. learn from) its neighbors, $Y_{iGVDt}*$ depends on adoption decisions of i's neighbors. We define "neighbors" as other farmers of the same land group living in the same village, and their influence on each farmer is summarized by the fraction of those neighbors who had adopted in the last period, denoted $\overline{Y}_{GVD,t-1}$. This fraction is lagged so as to avoid spurious contemporaneous correlations between different neighbors' decisions. In some empirical specifications we experiment with other variables to capture neighborhood influences, such as the proportion of neighbors who were "successful" adopters (i.e. for whom new HYV seed adoption led to above average yields). We assume two land groups in each village, so $G = S, L$ (S signifies the smaller landholder group while L signifies larger landholder group).

$Y_{iGVDt}*$ would also depend on a vector of possibly time-varying household specific characteristics X_{iGVDt}, which includes information and production related variables, and on village specific characteristics Z_{VDt}. Information variables include education, age, access to agricultural extension services, own experience with technology, while production variables are land size, tenancy status, size of household, and credit access. Village level characteristics such as distance to markets, access to infrastructure, price of HYV seeds and fertilizers could also be potential determinants of adoption. We include a set of district dummies and time dummies in all Pooled OLS specifications. The basic econometric model is thus:

$$Y_{iGVDt}^{*} = \alpha_D + \delta_t + \lambda \, \overline{Y}_{GVD,t-1} + X_{iGVDt}\beta + Z_{VDt}\eta + u_{iGVDt} \qquad (1)$$

where u_{iGVDt} is a mean-zero disturbance term.

Y_{iGVDt}^{*} is, of course, unobserved. What is observed is the actual adoption decision of households. Since a household would adopt the new HYV seed only when its net benefits from adoption are positive, the observed model is:

$$Y_{iGVDt} = 1, \quad \text{if } Y_{iGVDt}^{*} > 0,$$

$$Y_{iGVDt} = 0, \quad \text{otherwise.}$$

Under these assumptions, the model for the probability of household i adopting the new variety becomes:

$$P\,(Y_{iGVDt} = 1) = P\,(Y_{iGVDt}^{*} > 0)$$

$$= P\,(u_{iGVDt} > -(\alpha_D + \delta_t + \lambda \, \overline{Y}_{GVD,t-1} + X_{iGVDt}\beta + Z_{VDt}\eta\,) \qquad (2)$$

We estimate equation (2) using a linear probability model. The estimated model is:

$$Y_{iGVDt} = \alpha_D + \delta_t + \lambda \, \overline{Y}_{GVD,t-1} + X_{iGVDt}\beta + Z_{VDt}\eta + u_{iGVDt} \qquad (3)$$

The linear probability model (LPM) was chosen over standard discrete choice models such as logit or probit for several reasons. For a similar technology adoption model, Munshi and Myaux (2005) argue that the decision rule in equation (3) is linear in variables and hence it is appropriate to use the LPM for estimation. Also, unlike standard probit or logit, the linear model permits controlling for household Fixed Effects or district dummies without biasing other coefficients. While Fixed Effects in standard probit or logit do not provide consistent estimates, a conditional logit model could consistently estimate Fixed Effects. However, the nature of the adoption decision at hand and the sample structure make the use of conditional logit unsuitable.[25]

A weakness of the LPM is that model predictions for the dependent variable could lie outside the [0,1] interval. This problem is typically severe when the mean of the dependent variable is close to either zero or to one (Maddala 1983; Bandiera and Rasul 2004), but in the dataset used for this study, the mean is 0.34 (which implies that, overall, the

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[25] In panel data, heterogeneity across households could be analyzed by applying a Fixed Effects specification. With a fixed household specific effect a_i included, both a_i and $\boldsymbol{\beta}$ would be unknown parameters that need to be estimated. The general model would be:

$$\begin{aligned} P(Y_{it} = 1 \mid \boldsymbol{X_{it}}, a_i) &= P(Y_{it}^* > 0) \\ &= P(a_i + \boldsymbol{X_{it}}\boldsymbol{\beta} + u_{it} > 0) \\ &= P(u_{it} > -a_i - \boldsymbol{X_{it}}\boldsymbol{\beta}) \\ &= F(a_i + \boldsymbol{X_{it}}\boldsymbol{\beta}) \end{aligned}$$

The probit model cannot provide consistent estimators of a_i and $\boldsymbol{\beta}$. In a logit model, however, Fixed Effects can be estimated as follows:

$$P(Y_{it} = 1) = e^{ai + Xit\beta} / (1 + e^{ai + Xit\beta})$$

This approach, however, has a shortcoming if the time horizon of the panel is short. When T tends to infinity, the estimation of unknown parameters a_i and $\boldsymbol{\beta}$ are consistent. However, when T is small, as is the case with a typical panel data such as the Pakistan dataset, the limited number of observations lead to the incidental parameter problem and make the estimation of parameters biased. As a result, with small panels the emphasis is on estimating the common parameters $\boldsymbol{\beta}$, ignoring a_i. The problem with a nonlinear specification like the logit is that it is not possible to eliminate household unobserved effects a_i as it is possible in the case of a linear regression by a linear transformation such as the first difference. In discrete choice models the MLEs for a_i and $\boldsymbol{\beta}$ are not independent of each other, and even as N tends to infinity the MLE of $\boldsymbol{\beta}$ remains inconsistent (Hsiao 2003, Green 1997). Chamberlain (1980) suggests using a conditional logit model to remove household heterogeneity and estimate Fixed Effects models that have large N but small T (see also Green 1997).

adoption rate is 34%), and in the numerous regressions run, fewer than 2 percent of the predicted values lie outside of the zero-one interval. Thus, the problem of estimates lying outside the unit interval is very minor. We correct for heteroskedasticity and provide Huber-White robust standard errors. Based on these considerations, the LPM specification (Pooled OLS and Fixed Effects) appeared robust and was preferred over logit or probit estimation. We can gain further confidence from the fact that in regressions without household Fixed Effects, the results from the logit or the probit models are broadly similar to those estimated by the LPM.[26]

While we expect neighbors to potentially influence individual adoption decisions, we would expect this influence to be heterogeneous across individuals. Individuals with more precise prior information of the new technology would rely less on the information received from neighbors, while individuals with inferior prior information are expected to rely more on the information they receive from neighbors (Rogers 1962). One way to classify households into well-informed and ill-informed groups in rural Pakistan is by land ownership. We would expect larger (and better off) landholders to be better informed than smaller (and generally poorer) landholders regarding the new HYV seed technology. In our fieldwork we found larger landholders, in general, to be better aware of more recent agricultural practices and seed related issues. They were inclined to have higher levels of formal education and better access to public sources of information like agricultural

[26] We present results of OLS, probit and logit estimates in Appendix B, which shows that the level of significance of the different variables are quite similar across the three models, as are their coefficient estimates. For example, under all three models, the Lagged Cumulative Adoption (Village) variable is significant. Moreover, the coefficient of the Lagged Cumulative Adoption (Village) variable is 0.15 in Pooled OLS model, which is close to its marginal effect 0.169 calculated by the probit model. The logit coefficient is 0.70, which is also close to the Pooled OLS coefficient, as Amemiya (1981) shows that LPM coefficients are approximately 0.25 times the logit coefficients (excepting the constant term). Similar patterns hold for the other independent variables in the regressions.

extension services and the media. Consequently, the influence of neighbors is expected to be lower for them.

Our fieldwork suggests that in Pakistan, communication between small and large land owning farmers tends to be more infrequent than communication between farmers belonging to similar land groups. We therefore expect cross group influences to be smaller than within group influences. In the case of severe group-wise segregation, we expect cross group neighbor influences to be absent. In general, we would expect less informed households to seek out information from better informed households, but if the better informed households are wealthier larger landholders, small landholders may not communicate much with them. To estimate the impact of cross group influences and to see if within group effects are stronger for smaller landholders than for larger landholders we split the sample into large and small landholders and estimate the following regressions, where small landholders (*S*) are identified by the i subscript and large landholders (*L*) are identified by the j subscript:

$$Y_{iSVDt} = \alpha_D + \delta_t + \lambda_{SS}\,\overline{Y}_{SVD,t-1} + \lambda_{SL}\,\overline{Y}_{LVD,t-1} + X_{iSVDt}\,\beta_S + Z_{VDt}\,\eta_S + u_{iSVDt} \qquad (4)$$

$$Y_{jLVDt} = \alpha_D + \delta_t + \lambda_{LL}\,\overline{Y}_{LVD,t-1} + \lambda_{LS}\,\overline{Y}_{SVD,t-1} + X_{jLVDt}\,\beta_L + Z_{VDt}\,\eta_L + u_{jLVDt} \qquad (5)$$

Based on the discussion above we would expect that within group influences are positive for small and large holders alike, i.e., $\lambda_{SS} > 0$, $\lambda_{LL} > 0$, but the influence be stronger for small landholders, i.e., $\lambda_{SS} > \lambda_{LL}$. As we would expect within group influence to be stronger than cross group influence we would expect that $\lambda_{SS} > \lambda_{SL}$, and $\lambda_{LL} > \lambda_{LS}$. If cross group effects are absent we would expect $\lambda_{LS} = \lambda_{SL} = 0$.

Neighborhood Variable

The key coefficient of interest in the study is λ, which is the influence of neighbors on the adoption decision. The lagged cumulative proportion of adopters in a village (excluding self) is used as a proxy for the influence of geographical neighbors. To measure the influence of neighbors based on land size, we divide up households within a village into separate land groups, and then calculate the cumulative proportion of adopters (excluding self) in those different land groups.

We divide households into small and large groups using two different specifications, and we test the concept of neighborhood influence using each of the specifications. Dividing up farmers into small and large groups is not as unambiguous as dividing up farmers into different groups based on more clearly defined concepts like ethnicity or language. As a result, we consider different notions of groupings of small and large. The two specifications are:

(1) *Marginal versus Non-marginal Farms*: Households owning less than 5 acres (2 hectares) of land are marginal farms; those above 5 acres of land are non-marginal farms.

(2) *Small versus Non-small Farms*. Households owning less than 12.5 acres (5 hectares) of land are small farms; those above 12.5 acres of land are non-small farms.[27]

These land groupings are derived from the land distribution figures in rural Pakistan (Faruqee 1995). In 1990, around the time of the present study, half the farms in Pakistan

[27] Land groups can be defined in other ways as well. Land fertility varies considerably across the four sampled districts of the IFPRI panel survey. For example, in Faisalabad wheat yields on an average are almost twice as much as in Attock (adjusting for varieties grown). Accordingly, land ownership can be normalized by productivity of land (using village level aggregates) and then small and large landholders can be specified using particular cutoffs. We defined groups based on using normalized 5 acres and normalized 12.5 acres as cutoffs. These groupings gave similar results to the non-normalized land group findings, and as a result, we do not report results for them in this study.

were smaller than 5 acres in size, occupying less than 15 percent of total land. These farms could be classified as marginal and near-marginal farms. Farms sized between 5 and 12.5 acres could be regarded as small farms. About 80 percent of farms in Pakistan were smaller than 12.5 acres in size. Usually farms between 12.5 and 25 acres in size are considered as medium farms, and farms larger than 25 acres are considered large (Faruqee 1995). Medium farms were 12 percent, while large farms were barely 7 percent of total farms. In the IFPRI panel dataset used for this study, land distribution patterns were quite similar to national distributions. For instance, 55 percent of households owned less than 5 acres of land, 20 percent owned between 5 acres and 12.5 acres, while the remaining 25 percent owned above 12.5 acres.

In this study, we classify landholders into Marginal (less than 5 acres) and Non-marginal (more than 5 acres) groups, and Small (less than 12.5 acres) and Non-small (more than 12.5 acres) groups, rather than creating more specific and narrow groupings. Narrower groupings would often result in very few farmers belonging to the same group and weaken the concept of neighborhoods. Fieldwork interviews revealed that broader categories better indicated farmers' consultations and influences on each other. For example, a typical farmer is likely to interact just as much with other farmers with 2 acres more land as with farmers with 4 acres more land; he, however, is likely to interact less with farmers with 15 acres more land.

The Identification Problem

To identify the influence of neighbors in the adoption decision we use lagged cumulative adoption in the reference group within a village as the independent variable. The identification of neighborhood effects is, however, complicated by omitted variables: if unobserved determinants of adoption are correlated across neighbors and over time, spurious correlation between a household's adoption decision and its neighbors' previous period decisions could exist (Manski 1993). Unobserved household characteristics that are correlated among neighbors, e.g., latent ability or risk preferences, could give rise to similar adoption behavior. This is what Manski (1993) refers to as contextual effects. Also, all neighbors could receive a common shock, such as bad weather, or some village wide intervention by the agricultural extension office or an NGO, and their adoption decisions could be correlated, while not being dependent on each other. Another way estimates could be biased is if household level unobservable variables *not* correlated across neighbors (such as ability) are in fact determinants of adoption.

We can control for temporal changes by including time effects in regressions and we can control from some village level variables. We can also control for individual household's unobservable characteristics through Fixed Effects regressions as we have panel data. However, while Fixed Effects can control for time-invariant unobservables, it cannot control for unobserved time-varying characteristics that are spatially correlated within neighbors in the village. To the extent that these time varying latent factors remain influential in the adoption decision, the estimates of the lagged cumulative adoption variable would proxy for them and overestimate the role of neighbor effects.

In this study we attempt to mitigate the identification problems and we present arguments to defend the robustness of lagged cumulative adoption as an indicator of neighbor influence. We use a few findings of the empirical estimation results to do so. Firstly, our results suggest that neighbor effects are heterogeneous for large and small landholders. Neighbors' influences are stronger on small landholders (who are also typically less informed) than they are on larger landholders. This result signifies social learning rather than spurious correlation. Secondly, our finding that individuals are more influenced by those within their reference group but not influenced by those not in their reference group, suggests the influence of social peers. For our results to have this pattern in the *absence* of social learning, it must be the case that village level unobservable variables are be *totally* uncorrelated across small and large landholders (Munshi and Myaux 2005). It is highly unlikely that village level unobservable variables would be totally uncorrelated across small and large landholders, and we can thus infer the presence of social learning in our analysis. Finally, our results appear to suggest that farmers are not simply influenced by their neighbors' actions, but by their neighbors' experiences with adoption as well. This again is suggestive of a social learning process. We discuss these issues again in detail toward the end of this chapter after discussing our estimation results and their implications.

4.2.3 Descriptive Statistics

An important consideration in the adoption decision is the relative yields and profits of the two varieties of wheat. Table 4.1 compares the means and the coefficient of variation of the yield, the total earnings per acre of land, and the total sale per acre of land of new and old wheat varieties. Precise input expenditures on wheat are unavailable but since the old and the new varieties are similar in terms of input requirements (i.e., both are labor intensive, and fertilizer and irrigation sensitive), we can draw approximate conclusions from the available statistics.

The mean yield of the new variety is marginally higher than that of the old variety (6.8 percent) and this difference is not statistically significant. Also, the yield risks involved in both varieties appear similar. Farm households, however, may not find actual yield differentials of this magnitude enough of an incentive to switch to the new variety. In terms of earnings per acre and sale per acre, the new variety appears superior to the old variety in terms of both return and risk.

Table 4.1: Mean and Coefficient of Variation of Productivity Indicators by Wheat Variety

	Old Variety		New Variety	
Variable	**Mean**	**CV**	**Mean**	**CV**
Yield (mounds/acre)	12.13	73.78	12.96	74.45
Earning per acre (Rs/acre)	242.33	198.16	353.39	135.23
Sale per acre (mounds/acre)	3.27	205.56	4.61	141.49

In the IFPRI survey a set of questions was designed to understand the information sources that are important to farmers, but these questions did not directly concern usage of new wheat varieties. For example, sample households were asked: "What are your main sources of new agricultural information?" Households were asked to rank the information sources in order of their importance. Table 4.2 summarizes the percentage of households that listed the cited sources as the most important.

The importance of interpersonal communication is evident in Table 4.2. More households (35 percent) considered other farmers to be their most important information source, and some considered family and friends as their most important information source (8 percent). Public sources, such as radio and television, were considered most important by about a quarter of all households, followed by information from contact farmers.

Agricultural extension agents were not viewed as a major source of information by many farmers.

Table 4.2: Main Sources of Agricultural Information of Households

Sources of Information	Percentage of households
Extension Agent	8.2
Contact Farmer	13.6
Family/Friend	8.6
Other farmer	35.1
Radio/TV	24.4
Other media	1.4
Seed/Fertilizer Distributor	8.6

The geography and the cropping systems for the four surveyed districts – Faisalabad, Attock, Badin, and Dir – are fairly different. Faisalabad belongs to the major wheat producing zone in Pakistan. It has highly fertile land with a very good irrigation system where agricultural activities take place all year with farmers growing wheat, sugarcane and cotton. In the same province of Punjab as is Faisalabad, Attock belongs to the rain-fed or *Barani* zone. This area has no proper irrigation system and agriculture is largely dependent on the amount of rainfall in a particular year. Wheat is the major crop grown in Attock. Badin is a semi-desert like area, which relies on canal water coming from upstream for cultivation. Irrigation is not available in Badin at all times, and when available, it is often inadequate. Rice and sugarcane are the main crops grown there, while wheat is a secondary crop. Dir is an isolated mountainous area where some land is irrigated, some rain-fed. Most farmers in Dir grow a variety of crops such as maize, wheat, and some fruits. Given the varying cropping systems and geography of the four districts surveyed, it is expected that the adoption dynamics would be different across the districts.

In the entire sample, 23 percent of households had adopted the new variety in the first year. By the second year, this figure rose to 39 percent and by the last year, 42 percent of all households had adopted the new variety. The rate of adoption is different across the districts, Faisalabad, Attock and Badin with 47.3, 46.3 and 53.3 percent adoption, and Dir with only 26.5 percent adoption by the last year as shown in Table 4.3. It is worth noting that adoption is not steadily increasing in all the districts. While in Faisalabad and Badin adoption increased gradually over the three years, in Attock it rose dramatically in the second year and then fell in the last year, whereas in Dir it fell in the second year only to rise in the last year. Adverse weather conditions might have been partially responsible for declines in adoption in Attock and Dir.

Table 4.3: Percentage of Adopters by Year and District

	1986-87	1987-88	1988-89
All Districts	23.5	40.0	42.4
Faisalabad	33.3	41.7	47.3
Attock	27.1	61.3	46.2
Badin	14.9	50.0	53.3
Dir	18.6	14.7	26.5

While a large number of households never adopted, a sizable number of households switched to adoption or switched out of it within the sample years. The relatively high number of households switching in and out of adoption suggests that the fixed costs of adopting new HYVs were not very high. Iqbal et al (2002) argued the same about fixed costs of adopting new HYVs, reasoning that farmers did not need large amounts of cash or credit for buying new seed as most of them bought small amounts of seed and multiplied it on their own farms to use for several years. Table 4.4 (a) provides some statistics highlighting the fluid nature of adoption behavior. It gives the percentages of households in the last two years of the sample that had stuck to adoption (having adopted in the previous year), had switched to adoption (having not adopted in the previous year), that stuck to the old variety (non-adoption), or had switched away from adoption (having adopted the previous year).

Table 4.4 (a): Percentage households sticking to adoption (*Adp|Adp*), switching to adoption (*Adp|No*), sticking to the old variety (*No|No*), switching away from adoption (*No|Adp*)

	1987-88				1988-89			
	Adp|Adp	**Adp|No**	**No|No**	**No|Adp**	**Adp|Adp**	**Adp|No**	**No|No**	**No|Adp**
All Districts	15.4	24.4	51.2	9.0	21.0	16.4	41.3	21.3
Faisalabad	16.2	28.0	38.2	17.6	21.0	23.7	35.6	19.7
Attock	18.9	41.5	33.0	6.6	32.7	11.9	24.7	30.7
Badin	14.3	33.3	47.6	4.8	19.2	19.2	30.8	30.8
Dir	11.5	2.9	78.9	6.7	6.4	14.1	71.8	7.7

When households in all four districts are considered, it appears that a majority of households show inertia toward adopting. In 1987-88 and in 1988-89, 51.2 percent and 41.3 percent households stuck to the old variety. While 24.4 percent households switched to adoption in 1987-88, 9 percent switched away from adoption. What is surprising is that in the following year more households switched away from adoption (21.3 percent) than switched to adoption (16.4 percent). Adverse experience with adoption likely played a role in the high incidence of switching away from adoption. Households' behavior in 1987-88 and 1988-89 were very different in some districts. For example, in 1987-88, in Attock, 41.5 percent households switched to adoption, while only 6.6 percent switched away. In 1988-89, however, only 11.9 percent households switched to adoption while far more (30.7 percent) switched away. Households in Badin showed similar patterns, while most households in Dir were averse to adopting, with over 70 percent households never attempting to adopt. Even in Faisalabad, a relatively prosperous district with the highly fertile land and highly developed irrigation system, a substantial number of farmers switched away from adoption (17.6 percent in 1987-88 and 19.7 percent in 1988-89).

In most studies of technology adoption (e.g., Foster and Rosenzweig 1996, Munshi 2004) the phenomenon of households' reverting back to the old technology is not considered. Given its high occurrence in the present dataset this deserves closer scrutiny. Table 4.4(b) illustrates the findings of Table 4.4(a) in a slightly different manner by looking at conditional probabilities of households' adopting or not adopting given their actions in the previous year. When all four districts were considered, households' probability of moving away from adoption or P(No|Adp), was quite high (0.37 in 1987-88 and 0.50 in 1988-89).

Table 4.4 (b): Probability of sticking to adoption, *P(Adp/Adp)*; switching to adoption *P(Adp/No)*; sticking to the old variety *P(No/No)*; and switching away from adoption *P(No/Adp)*

	1987-88				1988-89			
	P(Adp|Adp)	P(Adp|No)	P(No|No)	P(No|Adp)	P(Adp|Adp)	P(Adp|No)	P(No|No)	P(No|Adp)
All Districts	0.63	0.32	0.68	0.37	0.5	0.28	0.72	0.5
Faisalabad	0.47	0.42	0.58	0.53	0.53	0.4	0.6	0.47
Attock	0.74	0.56	0.44	0.26	0.51	0.32	0.68	0.49
Badin	0.75	0.41	0.59	0.25	0.38	0.38	0.62	0.62
Dir	0.63	0.03	0.97	0.37	0.45	0.16	0.84	0.55

When adoption dynamics are compared for small landholders and larger landholders some interesting patterns emerge. Table 4.5(a) compares the adoption rates for marginal and non-marginal farmers and Table 4.5(b) gives the adoption rates of small and non-small landholders.

Table 4.5 (a): Adoption by Land Groups: Marginal versus Non-Marginal Landholders

	1986-87		1987-88		1988-89	
	Marginal Landholders	Non-Marginal Landholders	Marginal Landholders	Non-Marginal Landholders	Marginal Landholders	Non-Marginal Landholders
All Districts	20.6	26.8	35.9	45.4	36.6	48.9
Faisalabad	31.9	35.1	34.6	53.1	40	55.8
Attock	23.7	29.7	60.4	61.9	34.7	53.5
Badin	14.6	15.2	60	41.7	61.5	47.1
Dir	14.4	27	16.8	9.1	26.4	26.9

Table 4.5 (b): Adoption by Land Groups: Small versus Non-Small Landholders

	1986-87		1987-88		1988-89	
	Small Landholders	Non-Small Landholders	Small Landholders	Non-Small Landholders	Small Landholders	Non-Small Landholders
All Districts	21.6	28.8	37.6	48.1	40	49.5
Faisalabad	29.9	71.4	39.4	62.5	45.1	63.6
Attock	25	30.6	58.8	65.1	40.6	54.2
Badin	13.5	17.1	53.1	41.7	56.7	47.8
Dir	16.1	30	16.3	5.5	27.6	18.2

As would be expected, over the entire sample, larger landholders tended to be more frequent adopters. In Faisalabad and Attock, this was the case. However, in Badin and Dir the scenario was different, with larger landholders having lower adoption rates than smaller farmers. This might have been due to nature of wheat cultivation there. Unlike Faisalabad and Attock, in both Badin and Dir wheat was a secondary crop and farmers concentrated on crops such as rice, sugarcane, maize or fruits. They grew wheat intermittently and usually in small quantities for personal consumption. Many of these farmers also tended to prefer the taste of the older HYVs. While the larger landholders might have been growing the older HYVs for taste preferences, smaller landholders facing stringent food constraints might have preferred the newer higher yielding HYVs. In Faisalabad, adoption rates for all land groups steadily increased over time. In Attock massive adoption took place in 1978-88 only to drop in 1988-89. In Badin also, there was a large increase in adoption in 1988-89, after which adoption stagnated. In Dir, for smaller landholders adoption increased over time, but for larger landholders adoption declined in 1987-88, rising again subsequently.

Despite differences in adoption patterns, important common trends are visible across the districts. In all four districts, smaller landholders were more likely to switch away from adoption than larger landholders. Smaller landholders were perhaps more sensitive to crop failures and did not have the same risk bearing abilities as larger landholders. As a result they were quicker to switch away from adoption when their crops fare poorly. For example, in Attock, following the bad crop in 1987-88, adoption rates sunk for marginal landholders from 60.4 percent to 34.7 percent, while for non-marginal landholders the drop was more modest (from 61.9 percent to 53.5 percent).

Table 4.6 presents descriptive statistics for households by adoption status. Adopters were likelier to have large land-holdings than non-adopters, not holding other factors constant. Tenancy was more prevalent among non-adopters, as would be expected, while sharecropping was equally prevalent among adopters and non-adopters. Although formal credit use was extremely low among farmers, with only about 2.5% taking out formal loans at any point in time, adopters had higher use of formal credit. Non-adopters, however, were more likely than adopters to borrow from informal sources such as money-lenders, shopkeepers, and friends or family. These loans are largely for consumption purposes and are rarely used for investment activities such as agriculture; as such, they indicate households' economic status.

Table 4.6: Descriptive Statistics by Adoption Status

	All households	Adopters	Non-Adopters	Test of Equality (p-value)
Household and Village Characteristics				
Land Owned (acres)	11.84 (23.9)	14.55 (29.12)	10.25 (20.47)	0.004
Tenancy (yes=1)	0.13 (0.33)	0.08 (0.27)	0.15 (0.36)	0.001
Sharecropper (yes=1)	0.42 (0.49)	0.40 (0.49)	0.43 (0.49)	0.45
Formal Credit Use (yes=1)	0.024 (0.15)	0.038 (0.19)	0.016 (0.13)	0.02
Informal Credit Use (yes=1)	0.60 (0.49)	0.56 (0.49)	0.63 (0.48)	0.03
Household size	9.13 (4.67)	8.53 (4.29)	9.45 (4.83)	0.001
Age	48.81 (13.90)	48.09 (13.87)	49.20 (13.91)	0.2
Education of Household Head (years)	1.76 (3.63)	1.87 (3.71)	1.70 (3.59)	0.44
Extension Activity (yes=1)	0.07 (0.25)	0.09 (0.29)	0.05 (0.23)	0.01
Distance to Main Market (miles)	9.00 (4.88)	8.43 (4.74)	9.31 (4.92)	0.004
Land Groups (percentage in each group)				
Marginal Landholders	54.39	47.98	57.80	0.001
Small Landholders	75.00	70.45	77.42	0.01

Notes: Standard deviations are in parentheses. The test of equality is used to determine whether the means or proportions for adopters and non-adopters are equal.

Of the information related variables, it is interesting that educational levels do not appear to differ by adoption status. This is perhaps due to the general low levels of formal education in the sample villages. Adopters and non-adopters do not differ significantly regarding their age. Not surprisingly, adopters are almost twice as likely to communicate with agricultural extension agents, though in any given year the level of communication is extremely low for both adopters (5 percent) and non-adopters (9 percent). Finally, it is important to observe that adoption appears higher closer to the mandis or large markets, focal points of both economic activity and information exchange.

Table 4.7: Household Characteristics by Land Groups

	Landholders			
	Marginal	**Non-Marginal**	**Small**	**Non-Small**
Land Owned (acres)	1.44 (1.81)	24.03 (31.18)	3.17 (3.72)	37.46 (36.95)
Tenancy (yes=1)	0.17 (0.38)	0.07 (0.26)	0.16 (0.36)	0.04 (0.18)
Sharecropper (yes=1)	0.61 (0.49)	0.19 (0.39)	0.51 (0.50)	0.14 (0.35)
Formal Credit Use (yes=1)	0.01 (0.09)	0.04 (0.19)	0.015 (0.12)	0.05 (0.21)
Informal Credit Use (yes=1)	0.66 (0.47)	0.54 (0.49)	0.62 (0.48)	0.54 (0.49)
Household size	9.07 (4.44)	9.20 (4.93)	8.94 (4.20)	9.70 (5.82)
Age (years)	49.18 (13.59)	48.37 (14.27)	49.11 (13.55)	47.91 (14.90)
Education of Household Head (years)	1.20 (3.12)	2.42 (4.08)	1.26 (3.14)	3.25 (4.51)
Extension Activity (yes=1)	0.05 (0.22)	0.08 (0.27)	0.06 (0.25)	0.06 (0.24)
Distance to Main Market (miles)	9.13 (5.05)	8.84 (4.66)	8.86 (4.82)	9.42 (5.02)

Note: Standard Deviations are in parentheses

We conclude this section by comparing household characteristics by land size. As Table 4.7 shows, larger landholders appear to have higher use of formal credit, but lower use of informal credit. They have lower incidence of tenancy and sharecropping, higher levels of education, and higher contact with extension agents. In general, they tend to be economically better off than smaller landholders.

4.3 Estimation Results

We present regressions using both Pooled OLS and Household Fixed Effects specifications. All models reported in this section control for time effects and the Pooled OLS models control for district dummies. We also control for some village level variables, including distance to markets in miles. The villages for the sample were selected partly based on their differential distance from main market centers. Village level land characteristics such as whether cultivable land is canal irrigated or rain-fed appear to have very little variation within each district and hence district level controls would largely account for them. However, when included in regressions without district controls they explain very little of the adoption patterns. There is very little or no variation across villages regarding village level variables such as presence of banks, loan co-operatives, or health facilities, and the availability of fertilizer. Hence, these characteristics are not of much use in explaining variations in adoption patterns and we omit them from our analysis. Detailed village level information is always useful, but in our case the available information is not of much significance and importantly they appear orthogonal to the neighbor influence variables and other controls. As a result, in most regressions, distance to market is the only village level control.[28]

Household access to formal credit and agricultural extension services are potentially important determinants of adoption. We have information on formal credit use and extension service use in different periods, but not on access to credit or information. This is a shortcoming as 'use' measured contemporaneously is more endogenous to adoption decisions than access or availability. To mitigate the endogeneity concerns we use a variable indicating whether a household had ever used formal credit instead of a variable indicating their current use. This is a better, though not ideal, measure of credit access. Regarding extension service, we create a village level indicator of whether any household in the village in a given year communicated with an agricultural extension agent. Thus, the entire village is assumed to have had access to extension if any one household did.

4.3.1 Baseline Regressions with Neighbor Influence

Table 4.8 provides coefficient estimates for baseline Pooled OLS and household Fixed Effects regressions. Columns 1, 2 and 3 present results from Pooled OLS regression models while Columns 4, 5 and 6 present results from Fixed Effects regressions. Note that when we group farmers based on whether they are marginal (i.e. <2 acres) or non-marginal landholders within a village and define 'neighbors' as other wheat farmers in the village who

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[28] We have run some regressions with additional village level variables such as fertilizer availability, price of fertilizers such as Nitrogen, Urea and DAP, existences of services such as paved road, public transportation, and health facilities, the presence of political leadership, and the percentage of land in a village that is cultivated. None of these variables appear significant in the regressions, and because the data on them is incomplete we lose over 100 observations (around 20 percent) from the overall sample. We therefore decided to not include them in our reported regressions since they do not appear to impact adoption and their omission does not appreciably affect other variables of interest.

belong to the same land group, we refer to it as the 'Marginal/Non' neighborhood category; when we group farmers based on whether they are small (i.e. <5 acres) or non-small landholders, we refer to it as the 'Small/Non' neighborhood category. In contrast, the 'Geography' definition of neighbors is more inclusive and aggregated, and includes all other wheat farmers within the village regardless of their land ownership status. Columns 2 and 3 show that neighbors defined along landholding groups have a more statistically significant influence on household adoption decisions rather than the aggregated 'geographic' definition of neighborhoods. For the marginal/non grouping lagged cumulative adoption has a coefficient of 0.168, while for the small/non grouping lagged cumulative adoption has a coefficient of 0.183. The influence of the aggregated geographic neighbors appears statistically insignificant and the coefficient is slightly smaller at 0.15. Across the different definitions of neighborhood (or when we run regressions excluding the neighbor influence variables), the coefficients on all other variables do not change noticeably, implying that the lagged neighborhood adoption variables capture different aspects of adoption from the other variables, some of which measure other sources of information available to the households.

In contrast to the Pooled OLS results, the cumulative lagged adoption variables are statistically insignificant and the coefficients inconsistent in magnitude and sign in the household Fixed Effects regressions. In the Fixed Effects specification, we seek to explain the *change* in a farmer's adoption decision from one season to the next (from t to $t+1$) as a function of the *change* in that farmers' neighbors adoption patterns from the previous season to the current (i.e. from $t-1$ to t). With the lag, we effectively only have two data points per farmer, where the two data points were collected about 9 months apart. Not surprisingly, there is very little time series variation within a farmer in his neighbors' adoption patterns. Since adoption patterns of neighbors do not change a lot over the short 9-month period, we probably do not have enough variability in the data to identify its impacts. It is also possible that the discrepancy in results is explained by the fact that Fixed Effects estimates control for farmer-specific unobservables correlated with neighbors' adoption patterns that the Pooled OLS specifications fail to do, but the more likely explanation is that we don't have the right amount of data variability to precisely identify effects in a Fixed Effects context.[29]

Non-neighbor Determinants of Adoption

Of additional determinants of adoption a few results are of interest, mainly from the Pooled OLS regressions. When the household Fixed Effects specification is used, most of the household level variables of interest drop out since they are time-invariant. In the Fixed Effects results only access to extension information is consistently significant. In the Pooled OLS specifications we can also examine the impact of the time invariant variables.

Tenancy status negatively impacts adoption propensities and the result is strong in alternative specifications of the model. This result is not surprising as tenancy is linked to weaker property rights, poverty and credit constraints. A tenancy arrangement could potentially facilitate adoption if the landlord and tenant have a cooperative relationship, with the former providing the latter with capital such as new seeds and fertilizer. In Pakistan, however, for the most part the arrangement between the landlord and the tenants is not very

[29] It is worth mentioning that while the household fixed effect results are insignificant when lagged cumulative adoption is used as the neighbor influence variable, the results are very strong when contemporaneous cumulative adoption are considered. Whereas the coefficients for the geographical, marginal/non and small/non neighbor influence specifications are -0.13, 0.02, and -0.03 respectively when using the lagged cumulative adoption variable, when using contemporaneous cumulative adoption the coefficients are 0.31, 0.14, and 0.28 respectively, the geography and the small/non category being significant at the 95 percent level.

Table 4.8: Pooled OLS and Household Fixed Effects Models With Neighbor Influence

	Pooled OLS			Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)
	Geographic	Marginal/Non	Small/Non	Geographic	Marginal/Non	Small/Non
Lagged Cumulative Adoption (Village)	0.15			-0.13		
	(0.101)			(0.160)		
Lagged Cumulative Adoption (Marginal/Non)		0.168			0.02	
		(0.086)*			(0.134)	
Lagged Cumulative Adoption (Small/Non)			0.183			-0.034
			(0.089)**			(0.140)
Land owned (acres)	0.0001	0.0002	0.0001	0.0027	0.003	0.003
	(0.0011)	(0.0011)	(0.0011)	(0.0076)	(0.0076)	(0.0077)
Tenant	-0.129	-0.121	-0.128	0.021	0.021	0.023
	(0.049)***	(0.049)**	(0.050)**	(0.130)	(0.131)	(0.131)
Sharecropper	0.011	0.016	0.015	-0.234	-0.241	-0.237
	(0.045)	(0.045)	(0.045)	(0.123)*	(0.124)*	(0.123)*
Formal credit	0.102	0.099	0.112			
	(0.056)*	(0.056)*	(0.056)**			
Age of household head (years)	-0.002	-0.002	-0.002			
	(0.002)	(0.002)	(0.002)			
Household size	-0.0031	-0.0028	-0.0034			
	(0.0044)	(0.0044)	(0.0046)			
Education of household head (years)	-0.0078	-0.0079	-0.0077			
	(0.0064)	(0.0064)	(0.0065)			
Extension in village	0.043	0.042	0.036	0.145	0.16	0.147
	(0.054)	(0.054)	(0.054)	(0.065)**	(0.066)**	(0.066)**
Distance to market (miles)	-0.008	-0.008	-0.007			
	(0.004)**	(0.004)*	(0.004)*			
Year 3	-0.063	-0.071	-0.07	-0.001	-0.026	-0.016
	(0.039)	(0.038)*	(0.039)*	(0.048)	(0.047)	(0.048)
Attock	0.09	0.092	0.093			
	(0.058)	(0.058)	(0.059)			
Badin	0.031	0.017	0.06			
	(0.091)	(0.092)	(0.092)			
Dir	-0.147	-0.142	-0.131			
	(0.072)**	(0.071)**	(0.071)*			
Constant	0.567	0.559	0.534	0.451	0.406	0.428
	(0.120)***	(0.119)***	(0.122)***	(0.123)***	(0.121)***	(0.124)***
Observations	576	571	565	576	571	565
R-squared	0.13	0.13	0.13	0.05	0.04	0.04
Number of household I.D.				331	328	326

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

cooperative in nature. In the sample, only 5 percent of farmers used seeds they had received from their landlords. While the effects of tenancy on adoption are quite large, sharecropping status does not significantly predict adoption.

A result that is perhaps somewhat surprising is that land ownership has no impact on adoption behavior. While the new HYV seed is ostensibly scale-neutral we expect land size still to influence adoption because it is linked to economic well-being and credit constraints. This result bolsters the claims of Iqbal et al (2002) that the adoption of new seeds is not a capital driven investment. Adoption behavior, however, appears sensitive to the availability of formal credit in estimations. This is an important result from a policy perspective given the low levels of formal credit availability in rural Pakistan. Market access appears to be significant predictor of adoption as households in villages further away from main markets are less likely to adopt.

Of the several information related determinants of adoption none appear significant. The education level of household heads has no effect on adoption behavior. This result is robust to alternative measures of formal education. This suggests that the decision to adopt does not require the skills or information that formal education provides. Education is perhaps more important for agricultural management and marketing decisions, but not more basic decisions such as new HYV seed use. The access to agricultural extension services is not significant in any specification. When all three years of data are included it is positive and significant (not shown in Table 4.8), but once the first year is dropped from the sample (due to the lagging of the variable of interest), it is no longer significant. This could suggest the possibility that communication with extension agents only matters for early adopters seeking information, while in later periods, farmers make their decisions using other information sources. In general, however, the effectiveness of agricultural extension in the agriculture sector in Pakistan has been disputed in the literature (e.g., Heisey 1990, Faruqee 1995) and the fieldwork for this study tends to corroborate this. A majority of households we interviewed did not have any contact with extension office workers, and while larger landholders appeared to have more contact with extension workers, the smaller landholders had very little contact.

Other variables such as age and household size have no influence on adoption. Alternatives to household size such as the dependency ratio or the number of male adults in a household do not have any significance either. This is perhaps to some extent due to the fact that the new HYV seed technology is not meaningfully different in terms of labor requirements from the old HYV seeds. Also, with increased mechanization of agricultural cultivation in Pakistan, labor shortage is of less importance to farm households.

4.3.2 Own Experience and Neighbor Influence

We conduct our empirical analysis with two indicators of own experience. The first simply uses the lagged dependent variable as a regressor to see how past decisions influence the present. Using the lagged dependent variable in Pooled OLS could potentially, though not always, lead to inconsistent estimates (Wooldridge 2003). Using the lagged dependent variable could lead to bias especially in Fixed Effects regressions. The lagged dependent variable and the residuals in the transformed model are correlated to the order $1/T$, T being the number of time periods in the data (Hsiao 2003). Since $T = 3$ in the Pakistan dataset, this bias could be severe.

As an alternative to using the lagged dependent variable we use a variable that indicates household experience with adoption. A household would be highly likely to stick to adoption if it were successful in using the new HYV seed the previous year. It would be less likely to stick to the HYV seed if it had an adverse experience with adoption. We define a variable that is 1 if in the previous year an adopter household had a successful experience, and is 0 otherwise. We have information on harvest and we consider households with a better than the median village yield (harvest per acre) as households with a successful experience with the new technology.

Tables 4.9 (a) and 4.9 (b) give results from regressions that include indicators of own experience. In Table 4.9 (a) results are presented where the lagged dependent variable proxies for own experience, whereas in Table 4.9 (b) the lagged experience with the adoption decision proxies for own experience. (Since our variables of interest are the neighbor influence variable, from the point onward we do not present results for all the controls.)

When the lagged dependent variable is included in the Pooled OLS models, the coefficient of neighbor influence declines, and in fact neighbor influence is no longer significant for any specification as shown in Table 4.9 (a). However, the coefficients of land neighbors continue to remain higher than that of geography neighbors and this suggests that defining neighbors along land lines explains more than simply assuming that farmers are influenced by everyone around them. The coefficient of own experience ranges from 0.15 to 0.17 in the different specifications. What this suggests is that if a household had adopted the previous year, it is 17% more likely to stick to adoption this year, all else held constant. This is a relatively low coefficient for own experience and suggests that farmers' behaviors are not strongly path dependent. This is consistent with the summary statistics presented in

Table 4.9 (a): Neighbor Influence With the Lagged Dependent Variable Indicating Own Experience

	Pooled OLS				Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Own Experience	0.168	0.17	0.161	0.153	-0.544	-0.575	-0.579	-0.585
	(0.050)***	(0.053)***	(0.052)***	(0.054)***	(0.058)***	(0.060)***	(0.059)***	(0.060)***
Lagged Cum Adoption (Village)		0.049				0.256		
		(0.104)				(0.142)*		
Lagged Cum Adoption (Marginal/Non)			0.106				0.25	
			(0.088)				(0.116)**	
Lagged Cum Adoption (Small/ Non)				0.105				0.251
				(0.093)				(0.121)**
Observations	580	576	571	565	580	576	571	565
R-squared	0.15	0.15	0.15	0.15	0.3	0.31	0.32	0.32
Num of hhold I.D.					334	331	328	326

Robust standard errors in brackets

All models control for all other independent variables included in Table 4.8

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.9 (b): Neighbor Influence With the Lagged Experience with Adoption Indicating Own Experience

	Pooled OLS				Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Own Experience/Success	0.186	0.176	0.18	0.176	-0.42	-0.417	-0.425	-0.412
	(0.063)***	(0.064)***	(0.064)***	(0.064)***	(0.087)***	(0.088)***	(0.088)***	(0.089)***
Lagged Cum Adoption (Village)		0.148				-0.034		
		(0.107)				(0.157)		
Lagged Cum Adoption (Marginal/Non)			0.166				0.077	
			(0.090)*				(0.132)	
Lagged Cum Adoption (Small/Non)				0.181				0.063
				(0.094)*				(0.138)
Observations	538	538	535	528	538	538	535	528
R-squared	0.14	0.15	0.15	0.15	0.14	0.14	0.14	0.13
Num of hhold I.D.					305	305	304	301

Robust standard errors in brackets

All models control for all other independent variables included in Table 4.8

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.4 (b) that pointed out that the probability of all households sticking to adoption was 63 percent in the second year of the sample and only 50 percent the third year.

The results from the Fixed Effects models appear unreasonable since own experience has a very strong negative coefficient. This is indicative of the bias in Fixed Effects with the inclusion of a lagged dependent variable. Interestingly, neighbor influences are significant in the Fixed Effects estimation with a coefficient of around 0.25.

The results for own experience in Table 4.9 (b) are broadly similar to the results from using the lagged dependent variable with one distinction. In the Pooled OLS models while own experience is significant and its coefficient is around 0.18, the neighbor influence coefficients remain significant for land neighbors. Importantly, the neighbor influence is as important as own successful experience. The Fixed Effects results, however, continue to appear inconsistent. In the regressions following this section's discussion, we use the lagged experience with adoption to proxy for own experience. We do so as we feel this to be a better predictor of future behavior than the lagged dependent variable due to high level of switchers to and from adoption in our data. Also, we try to mitigate potential bias issues in the Pooled OLS models with lagged dependent variables. However, in the Fixed Effects models the bias seems to persist.

4.3.3 Neighbor Influence by Land Group – Within Group and Cross Group Effects

To analyze the differential impacts that neighbors might have on relatively well informed versus relatively poorly informed farmers, we partition the data into small and large landholders and run separate regressions. Small landholders, being poorly educated and having ill access to public information sources such as extension services or the media, are more likely to rely more on information received from neighbors than are their larger counterparts (recall from equations 4 and 5 that we would expect $\lambda_{SS} > 0$, $\lambda_{LL} > 0$, and $\lambda_{SS} > \lambda_{LL}$). Table 4.10(a) provides Pooled OLS estimates of within group influences for marginal and non-marginal and for small and non-small landholders. From Columns 1 and 2 it is apparent that their neighbors have a strong influence on marginal landholders (a coefficient of around 0.22). Conversely, Columns 3 and 4 suggest that non-marginal landholders are not influenced significantly by other non-marginal households (the coefficient ranges between 0.06 and 0.08 depending on the model). From Columns 5 through 8 we observe similar patterns when we analyze the small versus non-small groups.

These results lend credence to the neighborhood classification we choose since we would expect neighbors to matter more for smaller landholders. The results also imply that the lagged cumulative adoption variable is picking up information influences and this weakens the case for results being spuriously generated.

Table 4.10 (a): Neighbor Influence by Land Group – Pooled OLS Models

	Marginal Landholders		**Non-Marginal Landholders**		**Small Landholders**		**Non-Small Landholders**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Lagged Cum Adoption (Marginal/Non)	0.226 (0.129)*	0.237 (0.132)*	0.068 (0.117)	0.086 (0.128)				
Lagged Cum Adoption (Small/Non)					0.241 (0.120)**	0.237 (0.123)*	0.03 (0.144)	0.053 (0.156)
Own Experience/Success		0.113 (0.101)		0.239 (0.084)***		0.166 (0.080)**		0.154 (0.110)
Observations	310	294	261	241	435	408	130	120
R-squared	0.11	0.11	0.19	0.22	0.12	0.13	0.26	0.29

Robust standard errors in brackets
All models control for all other independent variables included in Table 4.8
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.10 (b): Neighbor Influence by Land Group – Fixed Effects Models

	Marginal Landholders		Non-Marginal Landholders		Small Landholders		Non-Small Landholders	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged Cum Adoption (Marginal/Non)	0.059 (0.205)	0.098 (0.190)	0.151 (0.192)	0.22 (0.202)				
Lagged Cum Adoption (Small / Non)					-0.109 (0.186)	-0.022 (0.182)	0.23 (0.244)	0.424 (0.255)
Own Experience / Success		-0.596 (0.132)***		-0.229 (0.131)*		-0.441 (0.108)***		-0.408 (0.175)**
Observations	310	294	261	241	435	408	130	120
Num of Hhold I.D.	187	174	150	139	257	237	76	71
R-squared	0.06	0.2	0.06	0.1	0.04	0.13	0.11	0.21

Robust standard errors in brackets

All models control for all other independent variables included in Table 4.8

* significant at 10%; ** significant at 5%; *** significant at 1%

While reasonable conclusions can be drawn from the Pooled OLS estimates, when household Fixed Effects are controlled for the results disappear. Table 4.10(b) provides the household Fixed Effects estimates for group-wise regressions.

Tables 4.11 (a) and 4.11 (b) provide Pooled OLS and Fixed Effects estimates of within group and cross group influences. Individuals are expected to interact more with those similar to them, and depending on the rigidity of the neighborhood definitions, there would be little or no meaningful communication across groups. As such we would expect cross land-group influences to be small, and at least smaller than within group influences (from equations 4 and 5 we expect $\lambda_{SS} > \lambda_{SL}$, and $\lambda_{LL} > \lambda_{LS}$). If the cross group effects are absent we would expect $\lambda_{LS} = \lambda_{SL} = 0$.

Table 4.11 (a): Cross Group Influence – Pooled OLS Models

	Marginal Landholders		Non-Marginal Landholders		Small Landholders		Non-Small Landholders	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged Cumulative Adoption (other group)	0.019 (0.098)	-0.037 (0.107)	0.037 (0.130)	0.014 (0.158)	0.089 (0.069)	0.045 (0.073)	-0.155 (0.163)	-0.285 (0.240)
Lagged Cumulative Adoption (own group)		0.23 (0.149)		0.038 (0.153)		0.439 (0.150)***		0.178 (0.202)
Observations	278	276	237	234	308	307	119	109
R-squared	0.08	0.08	0.16	0.15	0.11	0.14	0.25	0.25

Robust standard errors in brackets
All models control for all other independent variables included in Table 4.8
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.11 (b): Cross Group Influence – Household Fixed Effects Models

	Marginal Landholders		Non-Marginal Landholders		Small Landholders		Non-Small Landholders	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged Cumulative Adoption (other group)	-0.108 (0.128)	-0.132 (0.136)	0.018 (0.254)	-0.053 (0.285)	-0.096 (0.126)	-0.111 (0.139)	-0.143 (0.435)	-0.74 (0.553)
Lagged Cumulative Adoption (own group)		0.122 (0.234)		0.168 (0.225)		0.078 (0.277)		0.491 (0.339)
Observations	278	276	237	234	308	307	119	109
Num of Hhold I.D.	170	168	136	135	203	203	71	64
R-squared	0.07	0.07	0.05	0.06	0.06	0.06	0.08	0.14

Robust standard errors in brackets
All models control for all other independent variables included in Table 4.8
* significant at 10%; ** significant at 5%; *** significant at 1%

Results indicate that cross group effects are entirely absent between the different land groups. Fieldwork suggests that interaction and communication is low but not absent between smaller and larger landholders. Heisey (1990) in fact suggests that larger landholders were early adopters, and often, smaller landholders purchased seeds from them. Therefore, it would not have been surprising to find evidence of larger landholders influencing smaller landholders (while the inverse certainly would make little sense since better informed individuals are not likely to be influenced by less informed individuals). The absence of cross-group influences suggests that while there may be interaction among farmers with different landholdings, it is not significant. Interpersonal exchange is thus strongly segregated along land groups. These results are robust to alternate specifications of the model.[30] The results imply that there is no significant "trickle down" effect from larger landholders' adopting early, i.e., larger landholders' earlier adoption does not facilitate smaller landholder adoption through transfer of information or exchange of seed. Apart from its social and policy implications, this result is important from a methodological standpoint. Munshi and Myaux (2005) use a similar result to argue that it strengthens the case that the lagged cumulative adoption variable picks up neighbor influence rather than spurious correlations. We discuss this later.

4.3.4 Influence of Neighbors' Experiences with Adoption

A household would extract more precise information from neighbors' experiences with decisions than by simply observing their decisions. Whether or not a neighbor was successful with adoption is likely to influence an individual's decision more than casually observing that a neighbor had adopted. Thus, using lagged cumulative successful adoption by neighbors is likely to be a stronger indicator of social learning than lagged cumulative

[30] The characterization of the different land groups (marginal/non, small/non) is such that in almost every village all four groups have sufficient representation. For example, all but one village has at least 20 percent representation of marginal or non-marginal or small landholders. Only two villages have less than 20 percent representation of non-small landholders. Thus, the weakness of the cross-group influence is not due to certain land groups being with poor or no representation in the villages. We run regressions dropping the few households in villages that have less than 20 percent representation of any land group and end up with estimates similar to those derived from the entire sample.

adoption by neighbors.[31] Also, as it is more closely linked to learning from neighbors, this variable is also likely to mitigate concerns of neighbor influence results being spuriously generated.

In Tables 4.12 (a) and 4.12 (b) results are presented for marginal/non-marginal and for small/non-small neighbors respectively, where lagged cumulative successful adoption and lagged cumulative unsuccessful adoption are used to indicate the nature and extent of neighbors' influence. We would expect that in the adoption decision successful adopters would matter more than unsuccessful adopters do, because the bad experiences of the latter could make adoption somewhat less attractive, while the formers' success would spur adoption. As with own experience with adoption, neighbors' success is judged by whether or not their wheat yields were greater than the median village yield. The results from Tables 4.12 (a) and 4.12 (b) are different from the previous regressions which included the lagged cumulative adoption variable in one critical aspect. While so far the neighbor influence variable has been significant in the Pooled OLS models, in this case the Pooled OLS models produce inconclusive results, and the estimated coefficients of neighbor influence also appear smaller than in the previous regressions. In stark contrast, the Fixed Effects models give us strong results.

From 4.12 (a) it is evident that in the Pooled OLS models the coefficients of lagged cumulative successful adoption are lower (around .10) than the coefficients of lagged

[31] The importance of neighbors' experience is particularly important in this study because of the high number of households that switch to or switch out of adoption. Households that had positive experiences with adoption in the last period are unlikely to switch away from it, while those with negative experiences with adoption might be more likely to switch away from it. The lagged cumulative adoption variable would include the unsuccessful adopters as well as the successful adopters. Since unsuccessful adopters are likely to negatively impact adoption (since many unsuccessful adopters may no longer use new HYV seed themselves), the lagged cumulative successful adoption variable ought to be a superior indicator of neighbors' influence on adoption.

Table 4.12 (a): Influence of Neighbors' Experiences for Marginal/Non Marginal Neighbor Groups

	Pooled OLS						Fixed Effects					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Lagged Cum Successful Adoption	0.125	0.117			0.109	0.062	0.431	0.452			0.401	0.419
	(0.120)	(0.152)			(0.121)	(0.158)	(0.216)**	(0.211)**			(0.223)*	(0.217)*
Lagged Cum Unsuccessful Adoption			0.096	0.173	0.064	0.152			0.216	0.231	0.122	0.13
			(0.141)	(0.148)	(0.139)	(0.151)			(0.214)	(0.208)	(0.220)	(0.213)
Own experience/success		0.195		0.199		0.198		-0.421		-0.412		-0.419
		(0.063)***		(0.063)***		(0.063)***		(0.086)***		(0.087)***		(0.086)***
Observations	558	530	558	530	558	530	558	530	558	530	558	530
R-squared	0.13	0.14	0.13	0.14	0.13	0.14	0.06	0.16	0.05	0.14	0.06	0.16
Num of hhold I.D.							319	302	319	302	319	302

Table 4.12 (b): Influence of Neighbors' Experiences for Small/Non Small Neighbor Groups

	Pooled OLS						Fixed Effects					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Lagged Cum Successful Adoption	0.134	0.208			0.085	0.149	0.497	0.581			0.63	0.674
	(0.171)	(0.185)			(0.192)	(0.207)	(0.270)*	(0.267)**			(0.312)**	(0.308)**
Lagged Cum Unsuccessful Adoption			0.139	0.183	0.102	0.119			0.043	0.134	-0.251	-0.175
			(0.161)	(0.162)	(0.180)	(0.180)			(0.255)	(0.251)	(0.292)	(0.286)
Own experience/success		0.187		0.191		0.189		-0.411		-0.403		-0.412
		(0.064)***		(0.064)***		(0.064)***		(0.088)***		(0.088)***		(0.088)***
Observations	550	523	550	523	550	523	550	523	550	523	550	523
R-squared	0.13	0.14	0.13	0.14	0.13	0.14	0.06	0.15	0.05	0.13	0.06	0.15
Num of hhold I.D.							315	299	315	299	315	299

Robust standard errors in brackets

All models control for all other independent variables included in Table 4.8

* significant at 10%; ** significant at 5%; *** significant at 1%

cumulative adoption in earlier regressions, the results also are of less significance. Furthermore, from a comparison of Columns (1) through (6), it is also not clear whether successful adopters have a stronger influence than unsuccessful adopters.

However, from the Fixed Effects regressions shown in Columns (7) through (12) a clearer picture emerges. The estimated coefficients in the Fixed Effects models for the lagged cumulative successful adoption variable are very high (larger than 0.40 in all specifications). Also, successful adopters quite clearly exert more influence than unsuccessful adopters.

In addition to the within group estimates reported above, we also run the same group-wise regressions and cross-group regressions as in the previous sections and we get expected results. The household Fixed Effects models suggest that the influence of successful neighbors is greater for the smaller landholders. Also, cross-group effects are entirely absent. In the Pooled OLS models while the influence of successful neighbors is greater for smaller landholders than for larger landholders, the difference is not significant. Cross-group effects remain absent in Pooled OLS models.

4.3.5 <u>Alternative Specifications</u>

In this section we explore alternative classifications of neighbors to investigate additional possibilities and to test for robustness of our present neighbor definitions. First, we define neighbors using partitions of landholdings other than the marginal/non-marginal and the small/non-small categories and check the influence of neighbors in those cases. Second, we explore neighbors based on educational attainment groups. If classifications of neighbor groups are weak or inappropriate, i.e., if individuals in those reference groups do not actually interact or learn much from each other, we would expect the associated within group lagged cumulative adoption variable to give poor results.

Alternative Land Groups

We sort households into small and large land groups using four different criteria: i) households with below and above 2.5 acres of land (the landless and near-landless versus others); ii) households with below or above 4 acres of land; iii) households with below and above 7.5 acres of land; iv) households with below and above 25 acres of land.[32] In Pakistan farm households with below 2.5 acres of land are considered landless or near landless. Households with over 25 acres of land are considered large and these are less than 10 percent of all farm households. We choose the 4 acre and 7.5 acre partitions because they are close to the cutoffs chosen for the main analysis (5 acres for marginal/non and 12.5 acres for small/non).

Estimates from regressions are presented in the four tables in Appendix C. The estimates reveal that none of the four classifications are as strong as the marginal/non or the small/non classifications chosen earlier. Not surprisingly, the strongest neighbor influence is obtained for the below and above 4 acre land group classification, since it is close to the 5 acre cutoff used in the study. In addition, cross group effects are missing for all land groups. The weak estimates for within group influence for the different classifications are consistent

[32] If we chose groups based on a 50 acre cutoff, the larger land group would have too few observations (less than 4 percent overall and with zero observations in many villages.) Thus, we ignore that classification.

with our expectations. They also add justification for our chosen specifications of land neighbors.[33]

Groups Based on Educational Attainment

The level of formal education is extremely low in the sample villages. Only 21 percent of household heads are literate, 15.6 percent are with over 5 years of education and barely 8 percent are with over 8 years of education. Given the generally low education levels we do not expect neighbors defined by educational attainments to be as strong a concept as neighbors defined by land groups. However, larger landholders are inclined to have more education. For example, while marginal landholders on average have 1.2 years of education, non-marginal landholders have 2.4 years of education, and while marginal and small landholders on average have 1.26 years of formal education, non-small landholders have 3.25 years of education (as shown in Table 4.7). Consequently, we might expect some broadly similar patterns between land and education.

We partition households into less and more educated groups using three criteria based on the education level of the household head: i) illiterate versus literate; ii) below and above 5 years of formal education; iii) below and above 8 years of formal education. The estimation results (presented in Appendix D) indicate that in only one of the three classifications, the estimates of lagged adoption is significant. When we run regressions

[33] We also check for neighbor influences by defining land group neighbors in nonsensical ways. For example, we group farmers randomly into two different groups and find that neighbor effects in technology adoption are non-existent. We also classify farmers with more than 20 acres of land and farmers with less than 1 acre of land in the same group while classifying the remaining farmers in another group. This and a few other absurd notions of neighbors also fail to explain adoption behavior. These results demonstrate that our chosen definition of land neighbors (marginal/non, small/non) are not significant simply by chance. Had that been the case, nonsensical definitions of neighbors could turn out to be significant predictors of adoption as well.

using the full sample, the literate/illiterate classification and the below and above 8 years of formal education classification produce insignificant results. Only when households are grouped based on 5 years of formal schooling is the neighbor influence significant with a high coefficient (0.17). However, when we split the sample by education groups and run regressions on the split samples separately within group influence is not important.

As we know from before, education itself is not a significant predictor of adoption of new HYV seeds. It appears that a concept of neighbor influence based on education does not strongly predict adoption either. However, the limited finding that neighbors' influence based on below and above 5 years of formal education is a significant predictor of adoption is a reassuring result, especially since landholding levels and education are linked and we get strong results for neighbors based on landholdings. The findings of our study suggest that socioeconomic criteria as the land classifications we use, and to a far lesser extent education, are means by which individuals in rural communities in Pakistan organize their social interactions.

4.3.6 <u>Spurious Correlation Sources and Alternative Explanations of Results</u>

The neighbor influence results we obtain could possibly be spuriously generated if omitted variables influencing the adoption decision are present such that they are correlated across farm households belonging to the same land groups within a village. Also, household level unobservable variables that effect adoption might lead to biased estimates. In this section we attempt to address such concerns. Findings of the empirical work give us reason to be optimistic that these problems, even if present, are not likely to be substantial.

Firstly, we found that the lagged cumulative adoption variable by land group, which we claim reflects neighbor influences, was significant for small landholders, while being insignificant for larger landholders. This is indicative social learning because we would expect smaller relatively ill informed landholders to be more sensitive to the decisions of their neighbors, while larger relatively well informed landholders would be less sensitive to the actions of others around them. Individual household level latent characteristics are unlikely to give rise to such results. For example, if household ability were influencing adoption, it is improbable that ability would play a role for one group of households but not the other group (accounting for differential ability levels).

Secondly, the absence of cross-group influences diminishes the likelihood that group and village level omitted variables' spuriously produce the neighborhood influence results we observe. The finding that large landholders do not influence small landholders and vice versa is suggestive that when we observe within-group neighborhood influences, it is likely to be indicative of social learning rather than the effects of common shocks or a common set of unobservables producing incidental correlations. Individuals are not influenced by everyone around them, or by everything that takes place around them. Rather, they are selectively influenced by others who are similar to them, and less so or not at all by those who are different from them.

Munshi and Myaux (2005) have an excellent discussion on how the lack of cross group influence suggests the absence of spurious correlation. We summarize it here briefly. Recall equations (4) and (5) that modeled within and cross-group influences. We modify them to include group and village specific omitted variables (C_t^{SV} for small landholders and C_t^{LV} for large landholders) and rewrite them as:

$$Y_{iSVDt} = \alpha_D + \delta_t + \lambda_{SS}\,\overline{Y}_{SVD,t-1} + \lambda_{SL}\,\overline{Y}_{LVD,t-1} + X_{iSVDt}\,\beta_S + Z_{VDt}\,\eta_S + C_t^{SV} + \varepsilon_{iSDt} \quad (6)$$

$$Y_{jLVDt} = \alpha_D + \delta_t + \lambda_{LL}\,\overline{Y}_{LVD,t-1} + \lambda_{LS}\,\overline{Y}_{SVD,t-1} + X_{jLVDt}\,\beta_L + Z_{VDt}\,\eta_L + C_t^{LV} + \varepsilon_{jLDt} \quad (7)$$

where Y_{iSVDt} is the decision of small landholders and Y_{jLVDt} is the decision of large landholders. From the equations it can be verified that if each of the omitted variables is auto-correlated, the lagged cumulative adoption variable $\overline{Y}_{SVD,t-1}$ would proxy for the village and group specific omitted variable C_t^{SV} in equation 6, and likewise $\overline{Y}_{LVD,t-1}$ would proxy for C_t^{LV} in equation 7. Thus, the within group influence estimates λ_{SS} and λ_{LL} could turn out to be spurious if the omitted variables C_t^{SV} and C_t^{LV} are auto-correlated, and we could get significant coefficients for λ_{SS} and λ_{LL} even if neighbor influences or social learning were absent. However, if land group-village level unobservables were truly driving the neighborhood influence results and were solely responsible for a spurious non-zero λ_{SS} and λ_{LL}, we would also observe non-zero cross-group effects (λ_{SL} , λ_{LS}) unless the omitted variables for the small and large landholder groups, C_t^{SV} and C_t^{LV} were orthogonal to each other. In other words, given the entire set of results we present (non-zero within group influence but zero cross-group influence), a plausible alternative explanation for the results is not simply correlated village level omitted variables, but an omitted characteristic for large landholders that is orthogonal to some omitted characteristic for small landholders.

Plausible alternative explanations are therefore significantly more complicated, since in the context of rural Pakistan, it is difficult to think of an omitted characteristic of large landholders correlated with technology adoption behavior, but at the same time uncorrelated with some omitted characteristic of small landholders (that itself influences small landholders adoption behavior). This gives us greater confidence that our estimates of neighbor influence are indicative of some underlying structural process such as learning or information exchange and not mere driven entirely by spurious correlations.[34]

Finally, we might find some added justification to rule out spurious correlation from our Fixed Effects results that show that the experiences of neighbors, not just their decisions, appear to impact the adoption decision. Furthermore, successful neighbors have more impact on adoption behavior than do unsuccessful neighbors. These results are strongly consistent with the presence of social learning (although we must remember that our Pooled OLS estimates for the same specification were inconclusive).

Other Explanations to Estimation Results

There might be alternative explanations for the results obtained as factors left out could potentially be determining of adoption. We discuss a few such issues here.

I. Unobserved Village Level Interventions. The federal or provincial government or some NGOs could have programs to promote the adoption of new technologies. The only such program in Pakistan that we can think of is village agricultural extension offices that aim to promote agriculture productivity and growth in rural areas. Fortunately, we can control for it in our regressions. Had we not controlled for this, it would have been an important omission since there is evidence that extension workers differentially interact with large and

[34] Large and small landholders might have differential access to water or irrigation facilities (Mustafa 2002). Larger landholders, being wealthier and politically more powerful are likelier to have greater access to water. In our dataset, however, this of concern mainly in the district of Badin where available water is canal irrigated. We do not have a variable indicating household level irrigation access, but to the extent it is important and is different across large and small landholders, it would be picked up by household land size, a variable we control for. There is no evidence that access to irrigation facilities changed differentially between large and small landholders over the period of our sample. Therefore, it is unlikely to be an omitted variable that would generate spurious results of neighbor influence.

small landholders and the omission could obscure estimates of the lagged cumulative adoption variable. In the sampled areas in Pakistan, we do not observe the existence of farmers' clubs or cooperatives that might facilitate adoption of new HYV seeds.

We have a reasonable amount of data on the state of infrastructure in the sampled villages (paved roads, availability of public transportation, irrigation facilities, etc.) and over time there appears to be no glaring change in observed infrastructure quality. Time and District dummies should pick up changes over time and space. To the extent the unobserved infrastructure changes are different across villages, we are unable to control for them. However, it is difficult to think of any such infrastructure change that would impact larger and smaller landholders differently and consequently produce spurious correlation.

2. Marketing Infrastructure and Price. One explanation for the observed adoption patterns across farmers could be due to the presence of economies of scale in the marketing of the new HYV seeds (Bandiera and Rasul 2004). If seed sellers or distributors are only willing to travel to villages where they are assured large markets, they would tend to travel to the more affluent villages and to villages that are closer to the main market centers. With marketing infrastructure changing over time, as seed sellers and distributors move into less developed markets, it might encourage adoption in those places. Thus, what we consider as neighbor influences might partly be attributable to market infrastructure changes. We have no measure of market infrastructure changes, and to the degree this is important, we cannot account for it. Finally, one variable we have not discussed is the price variable. It could be argued that wealthier farmers are likely to adopt first, and others would follow subsequently as the as critical input prices go down. We do not have information on the price of HYV seeds, but other input prices (e.g., price of fertilizers) remain stable over the sample years.

Regardless of this issue, limited cross-sectional variability makes price of limited use in a study like ours.

4.4 Summary

The Pakistan study points to the importance of interpersonal exchange in the technology adoption process. Our classification of neighbors based on socioeconomic similarities among farmers helps explain the impact of interpersonal exchange in technology adoption since a majority of interactions appear to take place among farmers who belong to similar land ownership groups. A major concern in analyzing the influence of neighbors in adoption is the potential for omitted variables to confound its estimates and produce spurious correlations. Our results address these concerns since the heterogeneity of neighbors' influences across small and large landholders and the lack of cross group influence point to a process of social interaction or exchange. Of the economic or production related factors, tenancy and access to credit appear to impact adoption behavior. On the whole, economic factors do not appear to be important determinants of adoption since the capital requirements for the new HYV seed technology are only modestly higher than the old HYV seed technology. However, information related factors are important in the adoption decision since they help highlight the subtle advantages of the new technology, which may not be readily transparent to farmers. We elaborate more on the findings and implications of the Pakistan study in the concluding chapter.

Chapter 5

Hybrid Maize Adoption in Malawi

Hybrid maize seeds were introduced in Malawi around the 1960s but the maize variety did not suit the consumption demands of Malawians. As a result its use never became widespread. By 1990, hybrid seeds that suited the consumption preferences of Malawians were developed. These seeds had vastly superior yields over the traditional maize varieties grown by farmers in Malawi. Still, by the late 1990s, only about half the population in Malawi were growing hybrid maize, lower than anticipated at the onset of their introduction.

This chapter is organized similarly to the chapter on the Pakistan study. Section 5.1 discusses the context within which the study takes place and introduces the evolution of hybrid seed use in Malawi. It explains the institutional and political considerations that were largely responsible for the late introduction of hybrid seeds suited to the consumption needs of Malawians, and discusses the subsequent slow diffusion process. Section 5.2 describes the sample and the data used in this study. The empirical methodology of the study is introduced in this section along with descriptive statistics of adoption behavior and various community and household characteristics. Section 5.3 discusses the estimation results along with their implications. In the Malawi study, we find that farmers faced significant economic barriers to adoption, but informational barriers were not very important. The role of neighbors is suggestive at best; we find no conclusive evidence of neighbors influencing adoption decisions. To explain these findings, we argue that the relatively low importance of neighbors' influence was due to the transparent nature of the technology that was introduced, and due to the stringent economic situation of farmers, which made adopting hybrids seeds difficult regardless of the information they possessed. Section 5.4 briefly summarizes the findings of the chapter.

5.1 Context

Like much of sub-Saharan Africa, Malawi is predominantly a poor and undiversified rural economy. Nearly 85 percent of the population lives in the rural areas. Most households involved in agriculture are subsistence households growing maize as a staple food. While maize only recently became the staple food grain in Malawi about 70 years ago, the per capita consumption of maize in Malawi is one of the highest in the world, making up a greater proportion of the nation's diet than in any other country in the world. As a result, although 90 percent of rural households grow maize (typically on less than one hectare of land), the nationwide maize production struggles to keep up with its consumption requirements. The popular Malawian saying *chimanga ndi moyo*, which means "maize is life," shows the importance of this crop to Malawians. Smale (1995, p. 820) further underscores its importance in her observation that " … the ideal of producing enough maize to meet household needs informs everyone's actions and rationalizes for their actions before, during and after the maize harvest."

Malawi faces significant food security problems due to severe droughts throughout much of the year. In the face of persistent food shortages farmers are unable to maintain soil fertility through customary practices like fallowing or crop rotation, and are forced to increase their mono-cropped maize area, further undermining the cropping system.

Developing high yielding seed technology and expanding its use is central to solving the problem of food security in Malawi.

To address Malawi's food security problems, the government introduced a public maize breeding program a few years after the major famine of 1949. The Department of Agricultural Research (DAR) continued to release high yield variety seeds, such as hybrids and open pollinated varieties for over thirty years. By 1988, however, high yielding maize cultivation was only about 7 percent of the total maize area. Several factors contributed to the slow diffusion of hybrid maize for such a lengthy period. In particular, the government's seed breeding program failed to develop seeds that catered to the consumption preferences of Malawi's households. Malawians preferred flinty maize varieties, the traditional maize they grew, commonly known as *chimanga cha makolo* or "maize of the ancestors" (Smale 1995). The traditional flinty varieties could be easily processed into smooth white flour used to prepare *nsima*, a stiff porridge, which is the staple diet of Malawians. The early hybrids that were developed were dented varieties, which had inferior processing characteristics and therefore, produced inferior quality flour. Moreover, the early hybrids did not store as well as the traditional flinty maize varieties, which made them unsuitable for year-long consumption. As a result, hybrid maize was used predominantly as a cash crop and the lower yielding traditional varieties were widely used for personal consumption.

Smale (1995) argued that Malawi's failure to develop appropriate hybrid seeds resulted from the exclusion of small landholders from the political process. The powerful tobacco estate owners who dictated Malawi's agricultural development strategy had no interest in pressuring the government to develop maize seeds that suited the preferences of subsistence smallholders. On the other hand, large group of diverse smallholders could not form a powerful enough interest group to advance their demands. While the government's efforts to improve maize productivity largely languished, in the 1980s foreign donors became involved in encouraging the development of high yielding maize that smallholders would consider suitable for personal consumption. An international collaboration between Malawian scientists and CIMMYT (International Maize and Wheat Improvement Center) scientists finally resulted in the development of a new vintage of hybrid seeds that were semi-flint, and thus enjoyed similar impressive processing qualities as the traditional varieties (unlike the dented hybrid seeds that were previously rejected by consumers). It was anticipated that the Green Revolution had finally arrived in Malawi.

In addition to desirable processing attributes, these semi-flint seed varieties also stored well and were resilient under drought and poor soil quality conditions, especially when used in conjunction with fertilizer. These qualities encouraged farmers to plant the new hybrid seeds (MH17 and MH18), and by the end of 1992, 24 percent of farmers in Malawi were using hybrid varieties. The parastatal agricultural market outlet, ADMARC (Agricultural Development and Marketing Corporation) played an important role in the diffusion process since it was a major supplier of fertilizers and seeds. ADMARC worked in collaboration with credit clubs that were financed by the parastatal Smallholder Agricultural Credit Administration (SACA) to supply inputs to farmers (Orr 1998). About 75 percent of seeds and fertilizers were supplied to farmers by credit clubs that delivered fertilizer and seeds as a package with a pre-determined fertilizer-to-seed ratio.[35] Despite its initial success in promoting adoption, this program later faltered for many reasons. Zeller (1998) points

[35] This method of supplying seeds and fertilizers as a package with a fixed fertilizer-to-seed ratio was flawed because it did not account for the differential soil qualities and planting times across the country (Heisey and Smale 1995).

out that the droughts of 1992 and 1994, in addition to the political promise to write off loans during an election year, led to widespread loan defaults and the eventual bankruptcy of SACA. While in 1992, 400,000 smallholders had received credit, in 1994 the number had dwindled to 34,000. The total area allocated to hybrid maize cultivation dropped from 25 percent (in 1992) to 18 percent (in 1994) of the agricultural land (Orr 1998). By 1995-96, adoption rates increased again with the distribution of free seeds and fertilizers. Following that, subsidies on credit and fertilizer were removed, a move that likely depressed hybrid maize use. The price of maize inputs and outputs (both hybrid and traditional varieties) continued to be regulated, and therefore, prices did not necessarily reflect market forces. Since prices were fixed they embodied scarcely any useful information, and consequently, it was not surprising that farmers were insensitive to official prices (Heisey and Smale 1995). The rain-fed nature of Malawi's agriculture made the maize harvest inherently unstable, and regardless of controls, relative prices remained unstable anyway.[36]

Adoption rates seemed to have stagnated at about 50 percent of maize farming households by 1997-98, the time of the survey data for the present study. However, since most farmers reused seeds from previous years, this adoption figure painted a more optimistic picture of the state of maize production in Malawi than it was in reality. The slow diffusion of hybrid maize was all the more frustrating because it had almost twice as much yield potential as the traditional varieties, and about 50 percent greater total factor productivity (Gilbert et al 1994). Hybrid seeds also appeared to perform well with low input

[36] Informal prices were difficult to gauge and reliable information on them was not available. For a thorough analysis of issues involving maize pricing in Malawi read Heisey and Smale (1995).

intensity and in low management conditions. For example, hybrid maize tended to offer higher yields than traditional maize even with low fertilizer use (Heisey and Smale 1995).

It can be argued that prior to the introduction of semi-flint hybrids around 1990, supply factors were largely responsible for the slow adoption of hybrids. In the post semi-flint era, however, it would appear that demand factors were constraining adoption as well. To be certain, seed supply issues were still important as excess demand for seed was evident in some years (Gilbert et al 1994). Seed supply was not always smooth as seed breeding took place in a rain-fed environment, and lack of rainfall frequently disrupted seed breeding. Furthermore, seed distribution was often inefficient since the state run National Seed Company (NSC) of Malawi did not have a clear idea of the demands of farmers in different parts of the country. However, it also appears that chronic poverty and the ravages of droughts weakened the purchasing power of a sizable number of the farmers, and they simply did not have the means to buy new seeds. In a CIMMYT report (1997, p.3) Melinda Smale provided a sobering assessment: " … the impact of the research that produced the new hybrids remains low because of intervening economic factors and institutional change. Research delivered on its promise – the right seed has been developed, and farmers know that. But production cannot increase if farmers cannot purchase and plant the seed."

When discussing the adoption of hybrid maize seeds, it is important to understand farmers' sources of these seeds since they may acquire seeds from a variety of sources. Farmers may buy seeds from commercial sources such as public or private sellers, exchange seeds with or buy seeds from neighbors or extended family members, or use seeds retained from previous harvests. Most farmers who grew hybrid seeds in 1997 used their own seeds or exchanged seeds with other farmers, sometimes the seeds being recycled for as many as six generations. As a result, exchange of seeds comprised an important element of interpersonal exchange among farmers. Though farmers were aware of the deteriorating yields of older seeds, very few bought new seeds directly from the market as they were unwilling to pay for new seeds. A study by CIMMYT (1997) estimated that only about 10 percent of the area was planted with 'new' hybrid seeds.

The literature on hybrid maize adoption in Malawi has concentrated mostly on the typical supply and demand related constraints. To date, the role of information factors in adoption has not been analyzed in much depth. This is perhaps due to the general perception that informational issues are not the main barriers to the adoption of hybrid maize. Since hybrid maize was far superior to the traditional varieties in terms of yield, it was thought that farmers would need very little persuasion to adopt. It appeared that more households would adopt hybrid maize if they had the ability to do so; however, the ability was largely hindered by capital constraints (Gilbert et al 1994). Farmers' access to formal sources of agricultural information was extremely limited. The state of agricultural extension service traditionally has not been very sophisticated in Malawi and its role in expanding hybrid maize use was limited. In contrast, farmer-to-farmer transfer of knowledge played a role in making adoption more attractive (Gilbert et al 1994). Usually farmers appeared to observe the performances of their neighbors who had adopted hybrid seeds already. It was also evident that many of these farmers adopted new seeds provided they had the financial ability to do so. Since the economic constraints most farmers faced were severe enough to preclude them from purchasing new seeds from the market, they exchanged hybrid seeds among themselves, even though the seeds might have been a few years old. Therefore, besides providing information, neighbors' also helped adoption through seed exchange.

In this chapter when analyzing the influence of neighbors in adoption, we explore only the geographic concept of neighborhood because it best captures the nature of local social interactions in rural Malawi. Within a Traditional Authority or a TA (which is the level below districts in the administrative hierarchy of rural areas), information dissemination is not segregated by any obvious ethnic or socioeconomic group. Unlike Pakistan, there was no compelling case for using a socioeconomic variable such as income or land size to define neighborhoods. In the customary setup of a TA, such metrics do not adequately capture boundaries along individual interactions.[37]

The principal social segregation in Malawi is on the basis of ethnicity or tribe. These identities are particularly manifest in 'home area' (TA or district where one was born or where one's parents came from), in mother tongue, and in religion. However, in general, rural Malawi at the community or TA level is quite homogeneous in terms of social groupings. Ethnicity or tribal affiliations matter more in terms of cross-TA or cross-district interactions. Since tribal affiliations matter in cross TA rather than within TA interactions we do not consider this concept either.

5.2 Empirical Analysis

5.2.1 <u>Data and Sample Design</u>

The data used for the Malawi study comes from the Malawi Integrated Household Survey 1997-98 that was carried out by the National Statistical Office of the Government of Malawi, in conjunction with the International Food Policy Research Institute (IFPRI). The Malawi survey dataset consisting of 12,960 households has been used in policy research on

[37] Personal correspondence with Todd Benson of IFPRI helped clarify this issue.

household behavior and welfare, distribution of income, and employment. The dataset has information on households' technology adoption decisions as well. The spatial coverage of the dataset is extensive, covering all of the 25 administrative districts in Malawi, and each of the four urban centers.[38]

The survey's rural households were chosen following a multi-stage clustered random sampling approach. In the first stage, Traditional Authorities (TAs), were selected from each of the 25 rural districts using the probability-proportional-to-size method. The median number of TAs selected in a district by this method was two. In the second stage, Enumeration Areas (EAs) were selected from each TA using the probability-proportional-to-size method, resulting in 12 EAs from each TA. Finally, 20 households were selected from each EA using simple random sampling. Thus, 240 households were selected from each TA, and from each district, a minimum of 240 households were surveyed. This method of sampling provides information on assigning weights/probabilities to each selected household.

Of the 12,960 households, 6,586 households were judged to have reliable consumption and expenditure information, and of those 6,586 households, 4,190 were maize growing households. As agricultural practices in the rural areas and urban centers are very

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[38] The dataset can be requested from the National Statistical Office (NSO) of the Government of Malawi at enquiries@statistics.gov.mw. Details of the dataset are also available at http://www.nso.malawi.net. Below is a list a of few publications using this dataset:

1. Mukherjee, Sanjukta and Todd Benson. 2003. The Determinants of Poverty in Malawi, 1998. *World Development* 31, no. 2: 339-358.
2. Benson, Todd. 2002. *Malawi: An Atlas of Social Statistics*. Zomba, Malawi, Washington D.C.: Government Statistical Office, Government of Malawi, International Food Policy Research Institute (IFPRI).
3. National Economic Council, National Statistical Office, and International Food Policy Research Institute. 2001. *Profile of Poverty in Malawi, 1998: Poverty Analysis of the Malawi Integrated Household Survey, 1997-98*. Mimeo, June (http://www.nso.malawi.net/data- on_line/economics/his/ determinants_of_ poverty.pdf).

different, the four urban centers were dropped from the dataset, leaving 3,997 households representing 24 districts and 43 TAs. We dropped another 483 households since they had missing values for several TA level variables. Of the 3,514 households we were finally left with, 1,828 grew traditional maize and 1,686 grew hybrid maize. Adoption of hybrid maize in the sample is 48 percent. Apart from detailed household level demographic and expenditure information, the dataset also collected information at the TA level regarding the socio-economic context within which the households were interviewed.

A potential shortcoming of the data for analyzing adoption behavior is its cross-sectional nature, which only provides us a snapshot of the adoption process. If diffusion has reached its steady state by the time a survey is conducted, then we may be able to discern which characteristics ultimately determine adoption decisions, although we cannot conclude anything about the dynamics of adoption. If diffusion has not reached its steady state, then the observed correlation between farmer households' characteristics and adoption might be due to factors such as the households' location relative to the point of origin of the innovation. Such results would be misleading. In the case of the present dataset since information was collected by the time hybrid maize seeds had been in circulation for a few years and not during the early stages of hybrid maize adoption, we can rule out that possibility. We expect the data to provide us with reliable estimates of the determinants of adoption.

5.2.2 Empirical Model

This study considers the adoption decision to be a binary choice: to either adopt or to not adopt. However, farm households often may use a new technology and an old one simultaneously. They might do so for reasons such as risk diversification or adoption by gradual experimentation. In Malawi, farmers have long had a tendency to prefer traditional maize over hybrid maize for personal consumption. In some cases, farmers grew hybrid maize to sell in the markets but traditional maize to consume for themselves. This tendency to grow both crops simultaneously decreased since the introduction of semi-flint hybrid seeds. In the dataset, a majority of households (about 87 percent) grew a single variety of maize and only a handful grew both varieties. The relatively low number of dual users implies that using the *extent* of adoption (percentage land allocated to hybrid seeds) as the dependent variable does not provide added insight into adoption dynamics. For this reason, we concentrate on adoption as a dichotomous choice by characterizing households growing any amount of hybrid maize as adopters.

As in the Pakistan study, the econometric model for this study is motivated by the random utility approach following Rahm and Huffman (1984). The decision to adopt a particular technology would be dependent on the comparison of its net marginal benefits over other options. In the present context, a maize producing household would adopt the hybrid variety if the expected profits from adopting it were higher than that from continuing the use of the traditional variety.

Household i would adopt the hybrid seed variety if its expected net benefits from adoption Y_i* are positive. The expected net benefits would depend on a vector of production and information related household specific characteristics X_i and TA specific characteristics Z_{TA}. The production variables include land size, tenancy status, size of household, and credit access, while information variables include education, age, and access to agricultural extension services. TA level characteristics would include variables such as distance to markets, access to infrastructure, natural disaster risk. Since a household is likely to be influenced by its neighbors in the TA, Y_i^* would also depend on the expected net benefits of its neighbors from adoption, denoted as $\overline{Y_{TA}^*}$. The basic econometric specification is:

$$Y_i^* = \alpha + X_i \beta + \lambda \overline{Y_{TA}^*} + Z_{TA} \eta + u_i \qquad (1)$$

where u_i is a mean-zero disturbance term. Y_i^* is, of course, unobserved. What is observed is the actual adoption decision of households. Since a household would adopt the new hybrid seed only when its net benefits from adoption are positive, the observed model is:

$$Y_i = 1, \qquad \text{if } Y_i^* > 0,$$
$$Y_i = 0, \qquad \text{otherwise.}$$

Since the expected net benefits of a household's neighbors from adopting the new technology ($\overline{Y_{TA}^*}$) is also similarly unobserved, we assume that the fraction of neighbors who have adopted in the current period, denoted by $\overline{Y_{TA}}$, acts as a signal to each household of their neighbors' perceived benefits from adoption, and this fraction summarizes neighbors' influences on a household's adoption decision.

Under such assumptions, the probability of household i adopting the new variety is:

$$P(Y_i = 1) = P(Y_i^* > 0)$$
$$= P(u_i > -(\alpha + X_i \beta + \lambda \overline{Y_{TA}} + Z_{TA} \eta)) \qquad (2)$$

The model can be made operational by choosing the distribution of the disturbance terms. We assume the disturbances are normally (and identically and independently) distributed, and employ Probit estimation.[39] We use this model to examine not only the decision to adoption hybrid maize, but also the decision to adopt hybrid maize using fertilizer. We do so since the subgroup of farmers using fertilizer while growing hybrid maize differ in meaningful ways from farmers growing hybrid maize without using fertilizer.

Neighborhood Variable

In this study we analyze the geographic concept of neighbors for which we use the contemporaneous cumulative proportion of adopters in a TA (excluding self) as a proxy. The use of this variable poses potential problems. In adoption studies, economists typically use lagged cumulative adoption to indicate neighbor influences. We, however, have information from only one time period and that prevents us from using the lagged variable. On practical grounds, assuming that individuals are influenced by their neighbors' contemporaneous decisions is plausible since individuals interact and communicate with each other leading up to the time of planting, and consequently, it is more likely they are influenced by their neighbors' current decisions rather than their previous decisions. Regardless of practical considerations, using contemporaneous cumulative adoption is theoretically problematic as it gives rise to what Manski (1993) referred to as the reflection problem, i.e., while an individual is influenced by his neighbors' decisions, in turn, he

[39] Unlike the Pakistan study we do not use to LPM model here. The cross-section nature of the data suggests that using LPM offers no added benefits. Interestingly, like the Pakistan study, in this Malawi study also, the results from LPM and the Probit model are very similar. This is due to the mean of the dependent variable being close to 0.5 and due to the large number of observations in the sample.

influences their decisions also. This implies that, in our study, we would not be certain of causal effects; however, we would know how neighbors' decisions and individual decisions are correlated (Bandiera and Rasul (2004) and Goolsbee and Klenow (2000) follow an analogous approach). It would still be important and interesting to distinguish whether any observed correlation was due to social interaction effects or due to unobservable village and individual level variables.

Apart from the reflection problem, another potential source of distortion to the neighborhood variable could arise from the identification problem since omitted TA level and household level variables could potentially confound its estimation. For the Pakistan study, the availability of panel data allowed us to mitigate the identification problem. With cross-section data, however, our choices become limited and we can only use TA and household level controls to limit the extent of the problem. What this implies is that we should be cautious and modest while interpreting the coefficient of contemporaneous cumulative adoption as an indicator of neighbors' influence.

5.2.3 <u>Descriptive Statistics</u>

An important consideration in the adoption decision is the relative yields and profits of the alternative maize varieties. Detailed productivity figures are difficult to determine from the available data as input information is inadequate. However, Table 5.1 provides some insight into the relative characteristics of the two types of maize. From Table 5.1 it is apparent that the median yield of hybrid maize was 1.65 times that of the traditional varieties and the differences are statistically significant (across regions, hybrid maize yield remains uniformly higher than traditional maize yield). This is a striking difference given that most hybrid seeds are recycled from previous periods and with every passing cycle, their yield potential drops quite significantly.

Table 5.1: Production Characteristics by Maize Variety

Variable	Hybrid Variety	Traditional Variety
Median Yield (Kg/Ha)	889.56	555.98
% maize farmers who use fertilizer	56.77	28.84
% who sell a portion	22.02	16.28
Median household sale income (MK)	600	280

The overall adoption rate in the sample is 48.4 percent. Adoption is highest in the country's Northern region, though soil there tends to be less fertile than in the southern region. As expected, over the entire sample, non-poor farmers adopted more frequently than poorer farmers. In the sample, 23 percent of households are classified as ultra-poor, 31 percent are poor, and 45 percent are non-poor.[40] The proportion of ultra-poor households is lower in the Northern region (18 percent) than in the Central region (23 percent) or the

Table 5.2: Percentage of Adopters by Region and Income Groups

Households	All Regions	Southern Region	Central Region	Northern Region
All	48.38	44.43	48.39	56.87
Ultra-poor	38.37	37.24	34.42	59.63
Poor	47.37	41.86	49.25	51.54
Non-poor	54.3	50.83	54.73	59.44

Southern region (27 percent). Paradoxically, in the Northern region, which represented about 15 percent of the households in the sample, the ultra-poor households had as high

[40] The poverty group classifications were developed as part of the poverty study on Malawi using the 1997-98 Malawi Integrated Household Survey (National Economic Council et al 2001).

adoption rates as the non-poor households. Table 5.2 highlights region and income group based adoption figures.

There is considerable heterogeneity in the adoption rates across districts within regions. For example, in the Northern region adoption rates across districts ranged between 29 to 77 percent, in the Central region between 21 and 78 percent, and in the Southern region they range between 9 and 78 percent. Given the diverse cropping systems and geography of the entire country, this is unsurprising.

Table 5.3: Definition of Explanatory Variables

Production and Demographic Factors	
Land	Land owned in hectares
Freehold Land	Dummy variable, 1 if household has land as freeholder
Customary Land	Dummy variable, 1 if household is customary land holder
Rent/Lease Land	Dummy variable, 1 if household rents or leases land
Institutional Credit Use	Dummy variable, 1 if household borrowed from a formal credit source previous year
Informal Credit Use	Dummy variable, 1 if household borrowed from informal credit source previous year
Salary Income Source	Dummy variable, 1 if household has individual(s) receiving salary
Urban Income Source	Dummy variable, 1 if household receives income from urban source/ relative
Log Livestock Value	Log of per capita deflated value of livestock owned (in Khwacha)
Household Size	Number of individuals in household
Dependents	Number of dependents in household
Sex	Dummy variable, 1 if household head is male
Information Factors	
Education	Average years of education of adults in the household
Age	Age of household head in years
Extension Office	Dummy variable, 1 if office of agricultural extension office is in district
TA Level Characteristics	
Resident MP	Dummy variable, 1 if TA/Ward resident is a member of the parliament
Travel Time to Market Center	Weighted index of time taken to reach nearest producers' market and nearest ADMARC; 1 if half an hour or less; 2 if half an hour to an hour; 3 if 1 hour to 2 hours; 4 if over 2 hours
Relative TA Wealth	Dummy Variable, 1 if TA poorer than neighboring TA
Natural Disaster Risk	Index of natural disaster risk: early rain, late rain, drought, food destruction by flood, by hail, and by pests; 0 if little risk; 1 if medium risk; 2 if high risk

Table 5.3 provides a list of all the production and information related household variables and the TA level control variables used for the empirical analysis of the study. Table 5.4 provides summary statistics of these variables by hybrid maize adoption status. On an average, adopters had larger landholdings than non-adopters. In Malawi most farmers have very small plots of land; around 60 percent farmers cultivate on less than 1 hectare of land. Of farmers with less than 1 hectare of land, 42 percent adopted hybrid maize, while of farmers with more than 1 hectare of land 56 percent had adopted. Apart from land, other indicators also suggest that adopters appeared to be wealthier than non-adopters (e.g., they owned more livestock); they also seemed to have superior abilities of managing income risks as they had more members in the household who had salaried incomes or who lived in the urban areas.

In Malawi there are three land tenancy regimes: the customary tenure system, the public tenure system or freehold tenancy, and the estate tenure system that include leases from the government. The customary tenure system is the largest and is operated on about 80 percent of the land. All customary land falls under the administration of the TA, and the chief of that jurisdiction allocates land among farmers. This system does not provide serious incentives for long-term large investments (Place and Otsuka 2001). The public tenure or freehold system covering the national parks and other gazetted land is a small portion of the land in Malawi and is more commercial in nature. The land falling under the estate tenure system, which is only 5 percent of agricultural land in Malawi, is the most commercial in nature. Not surprisingly, a higher proportion of hybrid maize growers used freehold land or leasehold land, while a higher proportion of traditional maize growers used customary land.

Table 5.4: Descriptive Statistics by Hybrid Maize Adoption Status

	All households	Hybrid Maize Growers	Traditional Maize Growers
Production and Demographic Factors			
Land (hectares)	1.02 (0.92)	1.16 (1.08)	0.90 (0.73)
Freehold Land	0.33 (0.47)	0.39 (0.49)	0.27 (0.45)
Customary Land	0.63 (0.48)	0.55 (0.49)	0.71 (0.45)
Rent/Lease Land	0.05 (.21)	0.07 (0.25)	0.03 (0.17)
Institutional Credit Use	0.06 (0.24)	0.09 (0.28)	0.04 (0.19)
Informal Credit Use	0.20 (0.40)	0.23 (0.42)	0.17 (0.37)
Salary Income Source	0.18 (0.38)	0.23 (0.42)	0.13 (0.33)
Urban Income Source	0.09 (0.29)	.10 (0.29)	0.09 (0.28)
Log Livestock Value (Kwacha)	3.38 (2.73)	3.60 (2.76)	3.17 (2.69)
Household Size	4.52 (2.31)	4.83 (2.39)	4.23 (2.18)
Number of Dependents	2.31 (1.72)	2.44 (1.77)	2.19 (1.67)
Sex of Household head	0.75 (0.43)	0.81 (0.39)	0.70 (0.46)
Information Factors			
Education (years)	3.06 (3.03)	3.79 (3.29)	2.38 (2.59)
Age of Household Head (years)	42.46 (15.77)	40.69 (14.48)	44.12 (16.73)
Availability of Extension Office	0.47 (0.50)	0.58 (0.49)	0.37 (0.48)
TA Characteristics			
Presence of Resident MP	0.68 (0.46)	0.67 (0.47)	0.70 (0.46)
Travel Time to Market Center / ADMARC	2.40 (0.91)	2.34 (0.93)	2.46 (0.89)
Relative TA Wealth	0.46 (0.50)	0.40 (0.49)	.51 (0.50)
Natural Disaster Risk	1.26 (0.39)	1.26 (0.39)	1.27 (0.40)

Note: Standard Deviations in Parentheses

Adopters were likely to have higher use of credit, both from institutional sources and from informal sources. Formal credit organizations played a decisive role in hybrid maize seed diffusion in the early 1990s as many of them sold or distributed maize seeds to their members. While they eventually stopped distributing seeds, individuals with access to institutional credit remained likelier users of hybrid maize seeds. The use of institutional credit was very low in the sample. Only 6 percent of households used it, a dramatic decline from the high levels of credit use in 1994, after which the institutional credit apparatus broke down due to financial mismanagement. The ideal variable for empirical analysis is credit access but in its absence we use the credit 'use' variable in our estimations. The endogeneity problem that might arise from this variable is moderated to some extent because the credit use information is from the previous year.

The household sizes of adopters were likely to be larger. Household size could be used as a proxy for labor availability and the ability of a household to diversify risks (especially in the Sub-Saharan African context). While household sizes of adopters were likely to be larger, their number of dependents was likely to be lower. Also, adopting households were more frequently headed by males than non-adopting households (81 percent adopting households were male-headed as opposed to 70 percent non-adopting households).

Of information related variables, education levels appeared to differ by adoption status. Education levels were extremely low but, on average, elders in adopting households had more years of education than elders in non-adopting households. Other indicators of education give similar diverging patterns between adopters and non-adopters. Adopters were a bit younger in age, but not noticeably so. In districts with agricultural extension offices, adoption was likely to be higher. On average, adopters tended to live closer to producers' markets and to ADMARC, which was very crucial for farmers since ADMARC was both a supplier of maize seeds to farmers and a buyer of maize from farmers. We use the presence of a Member of Parliament from the TA as an indicator of political representation of households. This does not appear to differ between adopting and non-adopting households, other factors not being held constant. Similarly, the risk of natural disaster does not vary between adopting and non-adopting households.[41]

We have so far drawn a distinction between hybrid maize and traditional maize growing households. However, a finer and very important distinction can be drawn between households growing hybrid maize applying fertilizer with households growing hybrid maize without applying fertilizer. Fertilizer applying households can plausibly be classified as *serious* adopters, distinct from non-fertilizer applying adopter households. Households in Malawi have numerous seeds sources and many households grow hybrid maize simply because they stumbled across them, be it from neighbors, or from family members living close by. Many of these farmers are essentially unaware of the seed type they possess, and hence are not adopters in the strict sense of the term.[42] Whereas farmers applying fertilizer to their hybrid maize are not incidental adopters, rather they are more conscious or active adopters.

We can present some statistics that emphasizes the telling differences between fertilizer users and non-users. Of the entire sample, 27 percent of the households grew hybrid maize applying fertilizer, which is 56.7 percent of all hybrid maize growing

[41] The risk of natural disaster is quantified as a composite index of TA specific risks of late rain, rain stopping early, destruction of food crop by drought, flood, hail, and by pests. Each risk is categorized as high, medium or low for each TA, from which a combined index of TA-specific risk is developed.
[42] I am grateful to Melinda Smale and Todd Benson of IFPRI for this insight.

Table 5.5: Descriptive Statistics by Hybrid Maize Adoption Status Depending On Use of Fertilizer

	Hybrid Maize Growers Using Fertilizer	Hybrid Maize Growers Not Using Fertilizer	Traditional Maize Growers
Production and Demographic Factors			
Land (hectares)	1.34 (1.27)	.91 (0.67)	0.90 (0.73)
Freehold Land	0.38 (0.48)	0.42 (0.49)	0.27 (0.45)
Customary Land	0.54 (0.48)	0.54 (0.49)	0.71 (0.45)
Rent/Lease Land	0.08 (.28)	0.04 (0.20)	0.03 (0.17)
Institutional Credit Use	0.13 (0.33)	0.04 (0.19)	0.04 (0.19)
Informal Credit Use	0.28 (0.44)	0.16 (0.37)	0.17 (0.37)
Salary Income Source	0.25 (0.43)	0.20 (0.40)	0.13 (0.33)
Urban Income Source	0.12 (0.31)	.07 (0.25)	0.09 (0.28)
Log Livestock Value (Kwacha)	3.96 (2.76)	3.13 (2.68)	3.17 (2.69)
Household Size	5.07 (2.45)	4.51 (2.28)	4.23 (2.18)
Number of Dependents	2.56 (1.79)	2.29 (1.73)	2.19 (1.67)
Sex of Household head	0.86 (0.34)	0.75 (0.39)	0.70 (0.46)
Information Factors			
Education (years)	4.47 (3.37)	2.89 (2.94)	2.38 (2.59)
Age of Household Head (years)	40.11 (13.61)	41.45 (15.52)	44.12 (16.73)
Availability of Extension Office	0.64 (0.48)	0.50 (0.50)	0.37 (0.48)
TA Characteristics			
Presence of Resident MP	0.68 (0.47)	0.65 (0.47)	0.70 (0.46)
Travel Time to Market Center / ADMARC	2.32 (0.94)	2.37 (0.90)	2.46 (0.89)
Relative TA Wealth	0.38 (0.48)	0.43 (0.49)	.51 (0.50)
Natural Disaster Risk	1.23 (0.35)	1.30 (0.42)	1.27 (0.40)

Note: Standard Deviations in Parentheses households. The median yield of households growing hybrid maize using fertilizer was 1,111.95 Kg/hectare, while the median yield for those growing hybrid maize without using fertilizer was 494.2 Kg/hectare, over two times as high. The median yield of hybrid maize growers not applying fertilizer was in fact lower than the median yield of the traditional maize growers (whose median yield is 555.98 Kg/hectare) and far lower than the median yield of households growing traditional maize using fertilizer (930.69 Kg/hectare).

A look at the summary statistics in Table 5.5 shows that hybrid maize growers using fertilizer had characteristics distinct from households not using fertilizer. In fact, some broad similarities could be noticed among non-fertilizer using hybrid maize growers and traditional maize growers. For example, these two groups had very similar land holdings, livestock, and institutional credit use. However, the differences of these two groups with fertilizer using hybrid maize households were more pronounced. As a result of these differences, in our empirical analysis, we will explore not only the adoption decision of hybrid maize but also the decision to grow hybrid maize using fertilizer.

5.3 Estimation Results

5.3.1 <u>Hybrid Maize Adoption Decision</u>

Table 5.6 reports coefficients estimates and the marginal effects using the standard probit model for the hybrid maize adoption decision. All specifications control for district effects, with several TA level variables also being controlled for. Column 1 reports results of regressions without neighbor influences, i.e., without the TA level contemporaneous cumulative adoption variable. In Column 2, the cumulative adoption variable is included to observe neighbor influences. Column 3 includes dummy variables for the poor and the non-poor households to distinguish how adoption might vary across different income groups, ultra-poor households being the reference group. Column 4 includes intersection terms of income groups and cumulative adoption. This was done to analyze if neighbor influences varied across households belonging to different income groups. If the cumulative adoption variable does in fact pick up neighbor influences, we would expect the influence to be heterogeneous across households. As in the Pakistan study, here also we would expect neighbor influences to be stronger for poorer and relatively ill informed households, compared to wealthier and better informed households.

First we discuss the results for the neighborhood influence variable and then we turn to the household level and TA level production and other information related variables. From Columns 2, 3 and 4 it is evident that cumulative adoption within the TA has a strong relationship with the individual household adoption decision. Column 2 suggests that the probability of a household's adopting hybrid maize increases 0.62 percent with a 1 percent increase in neighbors' present period adoption.

To estimate the differential impacts of neighbors on households belonging to different income groups we estimate a regression including two intersection terms: i) product of cumulative adoption and a dummy variable of whether a household is poor, and ii) product of cumulative adoption and a dummy variable of whether a household is non-poor (ultra-poor households being the reference group). Column 4 suggests that neighbors matter much less for the non-poor group than the ultra-poor group (25.6 percent less), and while the effect on the poor group is lower also (by about 6 percent), the difference is not significant. These results are suggestive of a social learning process, whereby less informed individuals are more influenced by their peers than are more informed individuals.

Table 5.6: Estimates of Hybrid Maize Adoption

	(1)		(2)		(3)		(4)	
	Estimates	**Marginal Effect**	**Estimates**	**Marginal Effect**	**Estimates**	**Marginal Effect**	**Estimates**	**Marginal Effect**
Land Owned (hectares)	0.189 (5.84)***	0.075	0.173 (5.35)***	0.069	0.152 (4.67)***	0.061	0.15 (4.62)***	0.06
Freehold Land	0.083 (1.06)	0.033	0.098 (1.26)	0.039	0.109 (1.39)	0.044	0.096 (1.22)	0.038
Rent / Lease Land	0.282 (2.44)**	0.112	0.285 (2.47)**	0.113	0.279 (2.41)**	0.111	0.272 (2.35)**	0.108
Institutional Credit Use	0.344 (2.97)***	0.136	0.352 (3.03)***	0.139	0.337 (2.90)***	0.133	0.332 (2.85)***	0.132
Informal Credit Use	0.025 (0.36)	0.01	0.037 (0.52)	0.015	0.019 (0.27)	0.008	0.026 (0.36)	0.01
Salary Income Source	0.237 (3.52)***	0.094	0.215 (3.17)***	0.085	0.181 (2.66)***	0.072	0.182 (2.67)***	0.073
Urban Income Source	0.089 (1.08)	0.035	0.076 (0.92)	0.03	0.08 (0.97)	0.032	0.079 (0.96)	0.032
Log Livestock Value (Kwacha)	0.018 (1.93)*	0.007	0.023 (2.41)**	0.009	0.015 (1.59)	0.006	0.015 (1.54)	0.006
Household Size	0.078 (3.39)***	0.031	0.073 (3.21)***	0.029	0.086 (3.71)***	0.034	0.083 (3.59)***	0.033
Number of Dependents	-0.049 (1.71)*	-0.02	-0.047 (1.65)*	-0.019	-0.033 (1.12)	-0.013	-0.03 (1.03)	-0.012
Sex of Household Head	0.017 (0.27)	0.007	0.023 (0.37)	0.009	0.018 (0.30)	0.007	0.023 (0.38)	0.009
Education (years)	0.069 (7.79)***	0.028	0.068 (7.62)***	0.027	0.063 (7.03)***	0.025	0.063 (7.03)***	0.025
Age of Household Head (Years)	-0.022 (2.55)**	-0.009	-0.021 (2.34)**	-0.008	-0.018 (2.04)**	-0.007	-0.018 (2.02)**	-0.007
Age squared	0.00014 (1.56)	0.00006	0.00012 (1.36)	0.00005	0.0001 (1.06)	0.00004	0.00009 (1.05)	0.00004
Availability of Extension Office	0.136 (1.42)	0.054	-0.005 (0.05)	-0.002	-0.037 (0.37)	-0.015	-0.047 (0.46)	-0.019
Presence of Resident MP	0.384 (3.36)***	0.151	0.212 (1.77)*	0.084	0.21 (1.75)*	0.083	0.204 (1.69)*	0.081
Travel Time to Market Center	-0.153 (5.32)***	-0.061	-0.148 (5.14)***	-0.059	-0.135 (4.66)***	-0.054	-0.134 (4.61)***	-0.053
Relative TA Wealth	-0.163 (1.57)	-0.065	-0.167 (1.58)	-0.066	-0.279 (2.56)**	-0.111	-0.305 (2.76)***	-0.121
Natural Disaster Risk	-0.323 (3.39)***	-0.129	-0.14 (1.36)	-0.056	-0.172 (1.66)*	-0.068	-0.186 (1.79)*	-0.074

	(1)		(2)		(3)		(4)	
	Estimates	**Marginal Effect**	**Estimates**	**Marginal Effect**	**Estimates**	**Marginal Effect**	**Estimates**	**Marginal Effect**
Cumulative Adoption (TA)			1.558 (5.00)***	0.62	1.435 (4.57)***	0.571	1.728 (4.54)***	0.688
Poor Households					0.231 (3.42)***	0.092	0.314 (1.77)*	0.125
Non-Poor Households					0.371 (5.27)***	0.147	0.695 (4.00)***	0.272
Cumulative Adoption (TA) * Poor							-0.158 (0.49)	-0.063
Cumulative Adoption (TA) * Non-poor							-0.643 (2.06)**	-0.256
Constant	0.107 (0.32)		-0.544 (1.50)		-0.775 (2.11)**		-0.892 (2.36)**	
Log-likelihood	-1944.02		-1930		-1916.01		-1913.27	
Observations	3514	3514	3512	3512	3512	3512	3512	3512

Absolute value of z statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%
District Fixed Effects included
Marginal effects are evaluated at sample means for continuous variables; for dummy variables they signify the changes due to the dummy variables increasing from 0 to 1

We now turn to discussing the impacts of the non-neighbor variables. The results point out that several production and information related factors are of significance in the adoption decision. Not surprisingly, size of land is a significant determinant of adoption, as is land tenancy status. Hybrid maize being largely a scale-neutral technology, larger land size is not necessary to adopt it. However, individuals with larger quantities of land have better access to capital and possibly to information, and hence are more likely to adopt. The same is true for households that are leasing or renting land from the government, who are around 11 percent likelier to adopt than customary landholders. While the agricultural practices of households cultivating in public land or freehold land tends to be more commercial in nature than the farmers occupying customary land (and summary statistics suggested that the former had higher rates of adoption), in the regressions there are no significant differences between the two groups.

Credit from institutional sources played a pivotal role in the early stages of hybrid maize diffusion because seeds were distributed to farmers by credit clubs as part of a seed-fertilizer package. While the institutional credit system faltered around 1994 for various reasons, despite its relatively subdued scale of operation, it continued to be of importance to farmers. Farmers who had used credit the previous year were around 10 percent likelier to adopt than farmers who had not used institutional credit. Credit from informal sources, in contrast, was not significant because those loans were likely used for consumption rather than for investment purposes. Households with off-farm income sources such as salary income or urban income were likelier to adopt as they had added sources of income and security. Of the remaining production related variables, the significance of variables such as household size and number of dependents suggests that households with better access to labor were more capable of adopting. Heisey and Smale (1995) pointed out that growing hybrid maize was more labor-intensive than growing traditional maize as land preparation tended to be lengthier, and crop management requirements, e.g., weeding requirements, higher.

Of the information related variables education was significant as a predictor of adoption, although its impact was not very substantial (a year's extra education increased the likelihood of adoption by less than 3 percent). The official sources of agriculture related information available to farmers in Malawi through services such as agricultural extension offices were quite weak. About half the sample TAs were without any extension offices, but it is important to recognize that the presence of extension did not automatically signal that extension workers were effective communicators of agricultural practices (Heisey and Smale 1995). The estimates seem to bear witness to this, with extension office availability in TA not being significant in determining adoption behavior.

Several TA level variables provide interesting insights into the adoption process. In Malawi, until recently, ADMARC had the responsibility of delivering inputs for maize production, marketing the maize output, stabilizing maize prices through maintaining storage facilities, and transporting maize to areas suffering food shortages (Smale and Jayne 2003). The present analysis corroborates the importance of ADMARC, as households with faster access to ADMARC and to market centers were higher adopters. Not surprisingly, households in TAs more prone to natural disaster risk had lower adoption levels. Finally, it appears that political representation facilitates adoption, because the presence of a Member of Parliament from the TA increases the probability of adoption by more than 8 percent. In fact, while poorer areas were less likely to have widespread adoption, in the presence of political power they could overcome some of the negative consequences of poverty.

The results strongly suggest that economic and production constraints were key barriers to adoption in Malawi. Questions, however, could arise about to what extent the cumulative adoption variable can capture the influence of neighbors. Though the role of interpersonal exchange as captured by the cumulative adoption variable is positive, due to the reflection problem (Manski 1993) we cannot rule out the possibility of this affect being a correlated rather than a casual affect.

The other issue that could potentially confound the estimates of neighbors' influence is the presence of unobservable factors that we cannot control for. It is possible that the cumulative adoption variable proxies for TA-specific omitted variables, such as infrastructure or price. The influence of price would be picked up to large extent by the district dummies, and therefore, could be ruled out as not being very substantial.[43] The available TA level infrastructure information suggests that infrastructure was more or less uniform within districts. Still, certain types of infrastructure might have varied across TAs, and this might have been driving part of the results of the cumulative adoption variable. To the extent this or other potentially unobserved factors determine adoption, our results on neighbor influence would be biased. However, the result that the coefficient of the cumulative adoption variable was larger for poorer households than for wealthier households indicates the presence of a social learning process, and suggests that our results are not entirely spurious.

Table 5.7: Predicted Hybrid Maize Use

		Probit Estimation Without Neighbors' Influence			**Probit Estimation With Neighbors' Influence**	
		Actual Hybrid Maize Use			Actual Hybrid Maize Use	
		No	Yes		No	Yes
Predicted Hybrid Maize Use	No	1394	521	No	1362	497
	Yes	433	1164	Yes	465	1188

The inclusion of the neighbor influence variable does not appear to improve the success of predicting of hybrid maize use. Table 5.7 provides a comparison of results for actual and predicted hybrid seed use using models that excluded neighbor influences (Column 1 specification of Table 5.6) with the models that included it (Column 4 specification of Table 5.6). While the model with neighbor influence makes 24 fewer

[43] Smale et al (1995) find that farmers in Malawi were largely unresponsive to input and output price variations since these prices were fixed officially. Also, it is difficult to capture price effects in cross-sectional studies due to limited variability. Time Series analysis is more productive for this purpose.

mistakes in falsely predicting traditional maize use than the model without neighbor influence, it makes 32 more mistakes in falsely predicting the adoption of hybrid maize.

5.3.2 Decision to Use Hybrid Maize with Fertilizer

We estimate adoption using an alternate dependent variable, namely, the use of hybrid maize seeds along with fertilizer. Of the maize farmers in the sample 27 percent grow hybrid maize using fertilizer, 21 percent grow hybrid maize without any fertilizer, 15 percent grow traditional maize using fertilizer, and 37 percent grow traditional maize without fertilizer. While fertilizer use is not a precondition to growing hybrid maize, we are more likely to classify true adopters more precisely by this variable. From a policy and social welfare standpoint it is important to encourage farmers to grow hybrid maize using fertilizer since only then the actual potential of hybrid maize can be realized.

The results of using hybrid maize with fertilizer as a dependent variable are reported in Table 5.8. The economic and production constraints remained important determinants of hybrid maize use with fertilizer. A comparison of estimates between Tables 5.6 and Tables 5.8 provides broadly similar outcomes of the predictors of adoption.

The role of neighbors, as captured by the cumulative proportion of hybrid maize and fertilizer users within the TA, however, is of less importance now. One explanation for this is that while farmers may exchange seeds with each other or may purchase seeds from neighbors, they do not exchange both seeds and fertilizers with neighbors or buy both seeds and fertilizer from them. As Column 2 of Table 5.8 shows, the probability of hybrid maize and fertilizer use increased 0.24 percent with a 1 percent increase in cumulative adoption in the TA and is significant only at the 10 percent level. The effects disappear when income group dummies are included in the model as shown in Column 3. Column 4 suggests that neighbor influences are heterogeneous across different income groups although the differences are not significant. While neighbor effects are significant at the 10 percent level for ultra-poor households, they are not significant for poor or non-poor households.

Table 5.8: Estimates of Hybrid Maize Use with Fertilizer

	(1)		(2)		(3)		(4)	
	Estimates	Marginal Effect	Estimates	Marginal Effect	Estimates	Marginal Effect	Estimates	Marginal Effect
Land Owned (hectares)	0.206 (6.36)***	0.06	0.207 (6.39)***	0.06	0.181 (5.52)***	0.052	0.18 (5.52)***	0.051
Freehold Land	0.034 (0.40)	0.01	0.062 (0.72)	0.018	0.063 (0.73)	0.018	0.061 (0.70)	0.018
Rent / Lease Land	0.284 (2.46)**	0.091	0.29 (2.51)**	0.093	0.271 (2.34)**	0.085	0.269 (2.32)**	0.084
Institutional Credit Use	0.453 (4.03)***	0.15	0.448 (3.99)***	0.149	0.441 (3.91)***	0.144	0.438 (3.87)***	0.143
Informal Credit Use	0.102 (1.38)	0.031	0.11 (1.48)	0.033	0.088 (1.17)	0.026	0.093 (1.23)	0.027
Salary Income Source	0.172 (2.50)**	0.052	0.165 (2.40)**	0.05	0.118 (1.69)*	0.035	0.118 (1.69)*	0.035
Urban Income Source	0.284 (3.25)***	0.09	0.277 (3.16)***	0.087	0.288 (3.27)***	0.09	0.286 (3.26)***	0.089
Log Livestock Value (Kwacha)	0.037 (3.56)***	0.011	0.039 (3.74)***	0.011	0.028 (2.67)***	0.008	0.028 (2.65)***	0.008
Household Size	0.075 (3.12)***	0.022	0.073 (3.02)***	0.021	0.093 (3.80)***	0.027	0.091 (3.73)***	0.026
Number of Dependents	-0.063 (2.07)**	-0.018	-0.062 (2.02)**	-0.018	-0.046 (1.49)	-0.013	-0.045 (1.45)	-0.013
Sex of Household Head	0.13 (1.87)*	0.037	0.129 (1.85)*	0.036	0.123 (1.76)*	0.034	0.128 (1.82)*	0.035
Education (years)	0.089 (9.78)***	0.026	0.088 (9.67)***	0.026	0.081 (8.81)***	0.023	0.081 (8.79)***	0.023
Age of Household Head (Years)	-0.01 (1.01)	-0.003	-0.01 (0.98)	-0.003	-0.007 (0.70)	-0.002	-0.007 (0.71)	-0.002
Age squared	0.00001 (0.06)	0	0 (0.02)	0	-0.00003 (0.26)	-0.00001	-0.00003 (0.25)	-0.00001

	(1) Estimates	(1) Marginal Effect	(2) Estimates	(2) Marginal Effect	(3) Estimates	(3) Marginal Effect	(4) Estimates	(4) Marginal Effect
Availability of Extension Office	0.236 (2.06)**	0.069	0.121 (0.91)	0.035	0.099 (0.73)	0.028	0.077 (0.56)	0.022
Presence of Resident MP	0.237 (1.93)*	0.066	0.206 (1.64)	0.058	0.202 (1.60)	0.056	0.194 (1.53)	0.054
Travel Time to Market Center	-0.105 (3.39)***	-0.031	-0.103 (3.32)***	-0.03	-0.083 (2.66)***	-0.024	-0.08 (2.56)**	-0.023
Relative TA Wealth	-0.172 (1.39)	-0.05	-0.166 (1.33)	-0.048	-0.305 (2.36)**	-0.086	-0.336 (2.54)**	-0.094
Natural Disaster Risk	-0.287 (2.61)***	-0.084	-0.208 (1.75)*	-0.06	-0.231 (1.92)*	-0.066	-0.238 (1.97)**	-0.068
Cumulative Adoption (TA)			0.849 (1.68)*	0.247	0.733 (1.42)	0.21	0.996 (1.64)*	0.284
Poor Households					0.164 (2.17)**	0.048	0.192 (1.13)	0.056
Non-Poor Households					0.478 (6.14)***	0.139	0.664 (4.06)***	0.193
Cumulative Adoption (TA) * Poor							-0.082 (0.19)	-0.023
Cumulative Adoption (TA) * Non-poor							-0.552 (1.31)	-0.157
Constant	-6.85 (.)		-6.844 (.)		-7.472 (.)		-7.603 (.)	
Log-likelihood	-1623.85		-1621.98		-1599.41		-1598.11	
Observations	3494	3494	3493	3493	3493	3493	3493	3493

Absolute value of z statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%
District Fixed Effects included
Marginal effects are evaluated at sample means for continuous variables;
for dummy variables they signify the changes due to the dummy variables increasing from 0 to 1

The general directions of these results are as anticipated. We would expect economic constraints to matter significantly in the decision to use hybrid maize with fertilizer since it requires more capital than using hybrid maize seeds only. We have to continue to remain cautious about drawing conclusions from the estimates of the cumulative adoption variable, though the differential impact of the cumulative adoption variable across income groups is suggestive of a social learning process. The estimates suggest that social learning, even if present, was not very strong.

Table 5.9 provides a comparison of results for actual and predicted hybrid and fertilizer use using models that excluded neighbor influences (Column 1 specification of Table 5.8) with the models that included it (Column 4 specification of Table 5.8). Results indicate that the inclusion of the neighbor influence variable does not improve the success of predicting of the adoption behavior of households. While the model with neighbor influence makes 5 fewer mistakes in falsely predicting the non-use of hybrid maize with fertilizer than the model without neighbor influence, it makes 13 more mistakes in falsely predicting hybrid maize use with fertilizer.

Table 5.9: Predicted Hybrid Maize with Fertilizer Use

		Probit Estimation Without Neighbors' Influence			**Probit Estimation With Neighbors' Influence**	
		Actual Hybrid Maize with Fertilizer Use			Actual Hybrid Maize with Fertilizer Use	
		No	Yes		No	Yes
Predicted Hybrid Maize with Fertilizer Use	No	2282	544	No	2269	539
	Yes	208	459	Yes	221	464

5.4 Summary

This chapter highlights the importance of economic barriers to adoption in Malawi. Due to capital constraints, farmers found it difficult to adopt hybrid maize, or to adopt hybrid maize using fertilizer. Informational factors were not very significant barriers to adoption. Informal exchange between neighbors likely facilitated hybrid maize adoption; however, due to data limitations, the relation we capture suggests correlation but not causation. Furthermore, neighbors' appeared not to have a strong role in the adoption of hybrid maize with fertilizer. While the neighbor influences we estimated using the cumulative adoption variable might be spuriously generated due to omitted variables that influence adoption behavior, the heterogeneity of the estimates across households (i.e., estimated neighbor influence being stronger for poorer and ill informed households than for wealthier and better informed households) suggest that we are successful in capturing social influence to some extent. We elaborate more on the findings of the Malawi study in the concluding chapter.

Chapter 6

Policy Implications and Conclusion

Our studies on Pakistan and Malawi analyzed the importance of economic and information related barriers to adoption, with an emphasis on the role of informal information sources, i.e., interactions with neighbors. From the studies, we have learned that in influencing adoption, informational constraints were relatively more important in the slow adoption of HYV wheat seeds Pakistan, while economic constraints mattered more in the slow adoption of hybrid maize in Malawi. These findings are consistent with the differing environments of the two countries and the different nature of the new technologies introduced. In this concluding chapter we discuss the findings and the policy implications of the Pakistan and Malawi studies. In the final section of the chapter, we attempt to elicit the broader lessons learned from these two studies in terms of empirical results, policy implications, and methodology, and we also suggest directions for further research.

6.1 Pakistan Study

This study highlights the significance of information related barriers to adoption, especially the role of interpersonal exchange. Our Pooled OLS estimations indicate that individuals' decisions are influenced by their neighbors' actions and that individuals are selective about their interaction with neighbors. Among Pakistani farmers, it appears that interactions regarding technology adoption practices are concentrated largely along land ownership lines, while cross group influences are absent. This indicates that information flow is not fluid across geographical spaces and that the social milieu is stratified along wealth lines.

An interesting finding is that the size of land ownership directly has no significant impact on adoption, likely due to the scale-neutrality of the new HYV seed technology. However, land ownership appears to influence adoption in a more indirect way by affecting households' communications and interactions: smaller landholders are slower to adopt because other fellow small landholders are also slow to adopt. As cross group neighbor effects are absent, the externalities from one group of landholders' adoption decisions do not permeate to other groups of landholders. Thus, if large landholders happen to be earlier adopters, small landholders do not necessarily benefit from them, and vice versa. This segregated communication network creates a situation where social inequality lowers economic productivity as information does not flow smoothly within a locality.

An important finding of the paper is that neighbors matter differentially for large and small landholders. The former, being better informed, are less sensitive to their neighbors' behavior while the latter, having limited access to formal sources of information, rely more on what their neighbors are doing. This result, along with the absence of cross land group influences, suggests that our use of the lagged cumulative adoption variable captures a social learning and exchange process rather than spurious correlation from omitted variables that are possible determinants of adoption. This argument is vital to the credibility of the Pooled OLS analysis.

Though our Pooled OLS results appear robust, the household Fixed Effects regressions cannot precisely identify the effects of changes in neighborhood adoption patterns on a change in individual adoption behavior. Since neighborhood adoption rates are lagged, we effectively only have two data points per farmer collected nine months apart. There is relatively little inter-temporal variation in adoption behavior within farmer panels over this short interval. Nevertheless, the Fixed Effects results indicate that farmers learn from the experiences of others around them, and their adoption propensity responds more positively to "successful" adopters who were able to increase yields than to "unsuccessful" adopters. This means that farmers look to gather as precise information as possible as to the agricultural practices around them.

Of the traditional production related determinants of adoption, tenancy strongly negatively impacts adoption. The tenancy regime is firmly entrenched in Pakistan and reform, though potentially beneficial for many reasons, is unlikely to be feasible. Therefore, tenancy reform would most likely not be a cost-effective way to promote new technology use. A determinant of adoption that should receive attention is formal credit since limited access to formal credit appears to hinder adoption. The availability of formal credit is very low in rural Pakistan, and it is exceptionally low for agricultural activities. The uncertain nature of agricultural activities and the longer duration of agricultural loans as opposed to loans for activities such as trading, where borrowers can repay loans faster, make agricultural loans unattractive to potential formal source lenders. As a result, though a challenging initiative, the government and NGOs should improve formal credit provisions for farmers.

A supply factor that likely influenced the pace of adoption but was not considered explicitly in our empirical analysis due to data limitations is seed development and distribution. Government research laboratories first developed pre-basic seeds and then basic seeds, eventually selecting registered farmers to multiply basic seeds to produce certified seeds. These certified seeds were sold by state-owned seed depots or private dealers to the entire farming population. Heisey (1990) argued that the quantity of certified seed available for sale in the market was typically lower than their demand. This was due to the exceedingly cautious approach of the seed development agencies that tended to supply seeds based on their perception of farmers' demand for seeds. Typically, they supplied seeds based on their own seeds production targets and the quantity of seeds sold from the previous year. The seed development agencies and their breeders had insufficient knowledge regarding farmers' demand or requirements of particular seed varieties and tended to multiply seed varieties based on the yields in their own plots of land, which were meant for testing seed yield performances. This often resulted in the unnecessary multiplication of seeds that were less preferred by farmers at the expense of seed varieties that were better suited to the farmers' preferences.

Apart from poor seed variety propagation, our fieldwork also found that the seed distribution process was inefficient. With seed prices fixed by the state government, graft opportunities opened up for both public and private seed distributors who often sold seeds at higher than official prices to well-off farmers. Most farmers preferred to purchase seeds from fellow farmers as they could get seeds at a cheaper price than from seeds depots or from private seed sellers. While this behavior was largely in reaction to the differential between the market price and other farmers' selling price for seeds, it was also at least partly due to the inconveniences and uncertainties of buying new seeds directly from the market. A more efficient seed development and delivery system could have possibly improved adoption rates.

Let us now revisit the importance of information in the adoption process. Agricultural extension services could be an effective and relatively inexpensive mode of promoting desirable agricultural practices among farmers. In the estimation results for the Pakistan study, extension access is not a significant predictor of adoption but this does not necessarily imply that extension services are unimportant in encouraging adoption; more likely it suggests that the existing extension services were ineffective in Pakistan, a finding that is corroborated by Heisey (1990) and Faruqee (1995). A main shortcoming of extension initiatives in Pakistan was that extension workers were inclined to be of assistance to the relatively wealthier and larger landholders, virtually overlooking the less wealthy, small landholders. If extension services had been more directed towards the needs of the poorer farmers, adoption dynamics could possibly have been different.

The influence of informal information sources in the Pakistan study was strong, largely stemming from the lack of strong and reliable formal sources of information. Low levels of education and poor access to agricultural extension services and public media created a vacuum that was filled by informal information exchange among farmers. Informal exchange of information, however, could have drawbacks since it could lead to the persistence of misleading or incorrect information and slow down the adoption of newer, improved seed varieties. In the case of new HYV wheat seeds, adoption was often not very attractive to farmers as the yield increase was not substantially greater than the old HYV seeds. On the other hand, the risk of disease was far lower in the newer HYV seeds, and this should have been the main motivation for farmers' adopting newer seeds. Heisey (1990) argues that farmers, however, were not well informed of the risks of disease in the older HYV seeds. Our findings also reveal that a lack of reliable formal information contributed to the continued use of older HYV seeds and the slow adoption of newer HYV seeds. When new technologies are ostensibly superior to older technologies, such as when the

HYV wheat seed appeared initially in 1965 possessing clear yield advantages over the traditional wheat varieties, formal information sources are perhaps not essential in spurring adoption (Lowdermilk 1972, Heisey 1990). However, to promote adoption of new technologies that are subtly yet consequentially different from the older technologies, as was the case with new versus old HYV seeds, there is no real alternative to providing farmers with credible formal sources of information.

Based on the importance of communication networks among neighbors, the World Bank supported Training and Visit (T & V) programs to disseminate information in rural areas in many developing countries. Agricultural extension workers were expected to introduce new technologies to certain 'contact' farmers in a village who would then experiment with the new technologies with the ultimate goal of influencing other farmers through their positive experiences. Purcell and Anderson (1997) recommend that for extension programs to be truly effective they must assess the needs of different socioeconomic groups and prioritize which groups to target. Target groups should be approached based on their needs and capabilities. Extension workers should not merely encourage the use of specific technologies or practices, but they should interact with farmers more closely to ensure their involvement in problem definition and to elicit their support for extension activities.

A T & V program supported by the World Bank to improve extension services in Pakistan in the 1980s achieved only modest success. Husain et al (1994) found that while measures of contact between extension workers and farmers had increased after the T & V program, the quality of advice provided by extension officers had not improved, and consequently, extension services failed to improve farmers' knowledge and efficiency. Thus, it is not sufficient for farmers to simply have access to extension service; for the service to be effective, the staff of the extension offices should be knowledgeable and well trained.

Our findings on how farmers interact with each other are important in facilitating the dissemination of formal information. Governments or NGOs keen on promoting adoption (for that matter any other positive social or economic action) should engage in information targeting depending on farmers' channels of communication in the intervention area. This could suggest targeting farmers from different social strata. In the case of Pakistan, the obvious policy recommendation is to target small landholders who appear to be excluded from the formal information system. Also, early adoption could be subsidized because of the multiplier effects involved in convincing farmers to adopt, which subsequently could appreciably influence the rate of adoption.

6.2 Malawi Study

This study points to the importance of economic constraints in the adoption of hybrid maize in Malawi, with poorer households being much less likely to adopt. Factors such as household credit access, tenancy status, indicators of economic wealth (e.g., land ownership) and non-farm income sources were significant barriers to adoption. The importance of informational barriers was less obvious.

In general, cross-sectional analysis of technology adoption behavior can be problematic. However, because the hybrid seed technology in question was in circulation for several years and not a completely novel technology, the estimates of production and information related constraints ought to give us credible insights into factors influencing adoption behavior. The estimation of neighbor influences in cross-section research is, however, more questionable due to the identification problem, which often cannot be accounted for satisfactorily. Disregarding the measurement problems in our analysis, we found neighbor influences to be rather weak when we considered the household decision to use hybrid maize with fertilizer. Results were stronger when we considered the adoption decision of hybrid maize alone. We should also note that the predictive power of regressions with neighbor influences included were not superior to regressions without neighbor influences, and the case for causal impact was not very strong.

The role of formal sources of information (such as agricultural extension) in promoting adoption was weak in Malawi, and education, while significant, was not very consequential either. The relatively low importance of information in determining adoption in a setup like Malawi should not be wholly surprising because of the nature of the technology being introduced. Hybrid seeds were vastly superior in terms of yield to traditional maize, and its taste was also very similar to traditional maize, making it very desirable for farmers to adopt. Generally, farmers appeared to be well aware of the superiority of the hybrid seeds but were unable to adopt due to economic constraints (CIMMYT 1997). Regardless, Smale and Heisey (1995) argue that the role of formal information sources were important as farmers often could not fully appreciate the promise of hybrid seeds. Because of economic constraints, lack of proper knowledge about hybrid maize seed use, and natural disasters, many adopters failed to get the expected high yields from hybrid maize seeds. Seeing their neighbors' experiences, farmers became pessimistic about the yield potential of hybrid seeds and were less inclined to adopt. Effective agricultural extension information could be crucial in creating awareness of the full potential of hybrid seeds and in adequately training farmers in proper crop management practices such as fertilizer use and irrigation requirements.

The economic barriers to adoption in Malawi remain exceptionally challenging. For a long time, the failure to develop proper seeds held back Malawi's agricultural growth. With the introduction of new seeds, there was optimism about Malawi's ability to achieve agricultural self-sufficiency; however, pre-existing widespread poverty, economic mismanagement by the government, and major crop losses due to frequent droughts hampered Malawi's growth prospects. The scale of the problem in Malawi is considerable. While access to credit and availability of inexpensive seeds and fertilizers have in the past helped intensify adoption, it is difficult for the government to provide such services with its limited resources. Given the level of poverty and food scarcity, it is not enough to facilitate the adoption of hybrid maize seeds; farmers also have to be encouraged and provided with resources to use hybrid maize with fertilizer.

6.3 Lessons Learned

Our Pakistan study on the adoption of new HYV wheat seeds produced some interesting findings. It showed that in the absence of strong formal information sources in Pakistan, informal channels of communication among farmers were an important source of information on agricultural practices. Farmers appeared to selectively interact with and be influenced by the actions and experiences of neighbors who had similar socioeconomic attributes, i.e., similar levels of land ownership. Reliable formal sources of information would likely have facilitated adoption more by providing comparative information on old versus new HV wheat seeds. Certain sub-optimal practices, such as the prevalence of old

HYV varieties, persisted partly because credible formal information was unavailable and households were following the actions of their neighbors who also had limited information. Apart from informational issues, economic constraints, such as lack of credit access and land tenancy status, also hindered the adoption process in Pakistan. Inefficiencies in the seed development and the seed delivery systems contributed to slow adoption as well (Heisey 1990). Despite these difficulties, the Green Revolution and the post-Green Revolution stages in Pakistan can be considered a success story.

Malawi's experience, unfortunately, has not been very positive. The success of most agricultural technologies is highly dependent on adequate rainfall or irrigation supply. Given this requirement, it was never realistically expected that the Green Revolution in Malawi would be as spectacular as in parts of Asia. Regardless, it was envisioned that the introduction of new hybrid maize seeds in Malawi would present food deficit households with the opportunity to become self-sufficient through maize production. Economic limitations, adverse weather conditions, and policy mismanagement all contributed to weak agricultural performance, and frustrated the diffusion of hybrid maize. Like Pakistan, credit access and land tenancy in Malawi were important determinants of adoption behavior. The role of information related concerns probably did not play as large a role in the slow diffusion of hybrid maize as did the economic and infrastructure related factors. Our findings are consistent with Smale's argument that farmers appeared willing to adopt, yet lacked the ability to do so (CIMMYT 1997).

The Pakistan study found our socioeconomic concept of neighborhood to be a meaningful concept in explaining adoption behavior. For Malawi, however, the local conditions and societal setup did not lend itself to a similar definition of neighbors based on a socioeconomic concept. Our analysis of physical neighbors in Malawi indicated that such neighbors likely did not have very strong influences on the household adoption decision.

We should be cautious about generalizing the findings of these two studies since each study emphasizes different barriers (informational versus economic barriers) to adoption. However, we can see certain common underlying behavioral patterns across households in both cases. For example, in both countries, the dynamics of information processing by individuals were similar in some ways: relatively wealthier and better informed individuals relied less on the information of neighbors than did less informed, poorer individuals. Also, farmers appeared to be influenced not simply by the actions of others around them, but by the resultant experiences of those individuals as well.[44] Certain economic constraints such as credit access and tenancy status appear to have similar roles in adoption behavior.

The findings of this dissertation have several methodological implications. We have demonstrated the inadequacies of cross-sectional data in analyzing the phenomenon of neighbor influence due to the presence of reflection and identification problems, which can frustrate its estimation. With panel data, we are in a much better position to mitigate these issues, but even with panel data, as shown in the Pakistan study, exceptional care is needed for accurate estimation. Regardless of its shortcomings, our cross-sectional study provided us with useful results on technology adoption behavior.

Finally, we turn our attention to the scope for further research and suggestions for improving the present study. Since there is tremendous interest among scholars and

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[44] Our Malawi study does not allow us to make this claim explicitly due to its cross-sectional nature. However, Smale et al (1997) confirm this claim based on fieldwork findings.

policymakers in understanding social and demographic factors influencing human actions or economic outcomes, detailed information on household level and local level social and demographic characteristics should be collected in survey studies. For example, while the findings on the importance of socioeconomic neighbors in Pakistan are a promising contribution, having data on household *zaat* or kinship group affiliation attributes could possibly have enriched our analysis. Similarly, in the case of Malawi, having household tribal or ethnic affiliation information could potentially have furthered our understanding of the role of neighbors, or at the least, it would have shed light on the importance of ethnic identity in predicting adoption behavior.

A potential shortcoming of our work is that we try to draw inferences about the actions of households' relevant neighbors from village or TA level cumulative adoption statistics. As Udry and Conley (2003) pointed out, this may not always be a good approximation of the influence of neighbors since households communicate differentially with members of their communities, thereby, being differentially influenced by their neighbors. Households are also not necessarily aware of the actions of everyone in their local area. Udry and Conley (2003) suggest collecting detailed information on individual communication patterns, i.e., data on who individuals communicate with, and the content and intensity of their conversations with others. Such detailed information would possibly have improved the precision of the estimates of neighbor influence.

The current study, however, shows that we can establish reasonable and insightful conclusions on neighbors' influence in technology adoption from survey data that were not explicitly collected to examine this phenomenon. For this we need to specify neighbors carefully and take steps to mitigate potential identification problems. Given the complex nature of the adoption process, the relevant local environment must be carefully considered and incorporated into the empirical analysis. Adoption dynamics, of course, depend not only on the environment where the technology is being introduced but also on the nature of the technology itself. Neighbors' influence would be more pronounced if the attributes of a new technology are less transparent to potential adopters and if formal information sources are weak, as the Pakistan study illustrates. On the other hand, the Malawi study suggests that neighbors' influence would be less pronounced if the attributes of a new technology are more transparent, as well as if there are significant economic barriers to adoption

APPENDIX A: Description of Focus Groups in the Pakistan Study

For the Pakistan study, four focus group meetings were conducted in April 2004. All the meetings took place in the district of Attock in the Punjab province. Two of the meetings were held in the village Bai in the *Tehsil* (the main administrative unit below district) of Hasan Abdal. The other two meetings were held in the village Hitar in the Tehsil of Feth-e-Jang. An official from an NGO based in Islamabad, the capital of Pakistan, accompanied the author on the field trips. The official was familiar with the villages and fluent in *Punjabi*, the local language. The author is fluent in *Urdu*, the national language of Pakistan, and while he understands Punjabi, he cannot speak it fluently. In collaboration with the author of this dissertation, the official moderated the focus group discussions. Farmers, especially the relatively poor ones, were more comfortable speaking in Punjabi, though they also appeared to understand the Urdu the author spoke.

In both Bai and Hitar, we sought the help of local agricultural extension workers and local NGO workers in organizing the focus groups. These local officials asked a few farmers from different socioeconomic groups to be interviewed by us. These farmers were not necessarily NGO members or frequent visitors to the extension offices. These initial contacts were asked to provide references and arrange for interviews with other possible contacts, and thus a "snowball sample" method was used to contact and interview more people and form the focus groups. The farmers' names were not recorded, in keeping with the IRB (Institutional Review Board) procedures of the University of Texas at Austin. Of the two focus group meetings at Bai, one was attended by ten wheat farmers from different socioeconomic backgrounds. The other meeting was attended by eight relatively poor small landholders. The focus groups in Hitar were made up of smaller number of wheat farmers. One of the groups consisted of five farmers who were relatively large landholders and the other group consisted of seven small landholders.

The focus group meetings were held in local community centers. The discussions were semi-structured and participants were encouraged to air agriculture related issues and challenges that were of importance to them. We asked farmers to identify the main problems they faced in adopting new HYV variety seeds, and attempted to ascertain their different channels of communication – own knowledge and experience, formal sources of information, and interaction with neighbors. Farmers were very forthcoming in their discussions and eager to talk, and despite some language barriers, communication was quite fluid. In the focus group discussion with farmers from different socioeconomic strata in Bai, the relatively wealthier farmers were more expressive while the poorer farmers were more reticent. The relatively less wealthy farmers were more comfortable and vocal in the group meetings when there were other farmers who were from similar socioeconomic backgrounds. The findings from the focus group discussions and other individual farmer interviews are incorporated in this main discussion of the Pakistan study in Chapter 4; we briefly summarize some of the main findings in the following paragraph.

Focus group discussions indicated that neighbors were an important source of information for farmers, especially the poorer ones who also tended to be small landholders. The relatively better off larger landholders had better access to agricultural extension workers and received frequent advice from them, while the poorer farmers complained of lack of access to extension facilities. The small landholders seemed to rely more on what other farmers, especially other fellow small landholders, were doing. Some of the small landholders stated that while they sought advice from large landholders, they were often reluctant to act similarly because they lacked the capital or the risk-taking ability. Farmers frequently cited lack of institutional credit as a major barrier to adoption. Since the focus group discussions were held in Attock, a rain-fed area, farmers frequently complained of poor irrigation facilities and said that their harvest was very often left to the mercy of the weather. In general, the larger landholders appeared to be better informed of the characteristics of new HYV seeds. It is interesting that at the time of the focus group discussions, most large and small landholders were still growing *Inqilab-91*, an HYV wheat seed that was introduced over ten years ago. They were satisfied with the high yielding Inqilab-91 and felt that the newer HYVs were not very promising. Incidentally, agricultural extension agents shared the same high opinion of Inqilab-91 *vis-à-vis* the newer HYVs. Farmers thus showed inertia toward adopting new seeds if the yield potential did not seem substantially high.

APPENDIX B: Comparison of Pooled OLS, Probit and Logit Estimates

Table B.1: Estimates Using Pooled OLS, Probit and Logit Models

	Geographic Neighbors			Land group Neighbors (Marginal/Non)		
	(1) OLS Coefficient	(2) Marginal Effect in Probit	(3) Logit Coefficient	(4) OLS Coefficient	(5) Marginal Effect in Probit	(6) Logit Coefficient
Lagged Cum Adoption (Village)	0.15 (0.101)	0.169 (0.107)	0.704 (0.474)			
Lagged Cum Adoption (Marginal/Non)				0.168 (0.086)*	0.182 (0.090)**	0.793 (0.401)**
Land owned (acres)	0.0001 (0.0011)	0.0001 (0.0011)	0.0005 (0.0046)	0.0002 (0.0011)	0.0002 (0.0011)	0.001 (0.0046)
Tenant	-0.129 (0.049)***	-0.149 (0.055)***	-0.721 (0.283)**	-0.121 (0.049)**	-0.141 (0.056)**	-0.684 (0.285)**
Sharecropper	0.011 (0.045)	0.017 (0.049)	0.056 (0.212)	0.016 (0.045)	0.022 (0.049)	0.08 (0.214)
Formal credit	0.102 (0.056)*	0.11 (0.058)*	0.465 (0.244)*	0.099 (0.056)*	0.106 (0.058)*	0.45 (0.247)*
Age of household head (years)	-0.002 (0.002)	-0.002 (0.002)	-0.009 (0.008)	-0.002 (0.002)	-0.002 (0.002)	-0.01 (0.008)
Household size	-0.0031 (0.0044)	-0.0038 (0.0056)	-0.0176 (0.0255)	-0.0028 (0.0044)	-0.0034 (0.0056)	-0.0161 (0.0255)
Education of household head (years)	-0.0078 (0.0064)	-0.0085 (0.0068)	-0.0361 (0.0296)	-0.0079 (0.0064)	-0.0085 (0.0068)	-0.0364 (0.0297)
Extension in village	0.043 (0.054)	0.049 (0.054)	0.205 (0.229)	0.042 (0.054)	0.047 (0.054)	0.201 (0.228)
Distance to market (miles)	-0.008 (0.004)**	-0.008 (0.005)*	-0.036 (0.021)*	-0.008 (0.004)*	-0.008 (0.005)*	-0.034 (0.021)*
Year 3	-0.063 (0.039)	-0.07 (0.045)	-0.331 (0.202)	-0.071 (0.038)*	-0.078 (0.043)*	-0.371 (0.198)*
Attock	0.09 (0.058)	0.085 (0.059)	0.352 (0.249)	0.092 (0.058)	0.086 (0.059)	0.359 (0.250)
Badin	0.031 (0.091)	0.03 (0.092)	0.134 (0.381)	0.017 (0.092)	0.016 (0.092)	0.08 (0.388)
Dir	-0.147 (0.072)**	-0.17 (0.072)**	-0.811 (0.356)**	-0.142 (0.071)**	-0.166 (0.071)**	-0.791 (0.353)**
Observations	576	576	576	571	571	571
R-squared	0.13			0.13		
Log-likelihood		-343.82	-343.64		-340.13	-339.89

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

In Probit model, marginal effects are evaluated at sample means for continuous variables; for dummy variables they signify the changes due to the dummy variables increasing from 0 to 1

APPENDIX C: Within and Cross Group Estimates With Alternative Land Group Specifications

Table C.1: Within and Cross Group Influences for Households With Below and Above 2.5 Acres of Land Holding

	Pooled OLS			Fixed Effects		
	All households	Smaller Landholders (<2.5 acres)	Larger landholders (>=2.5 acres)	All households	Smaller Landholders (<2.5 acres)	Larger landholders (>=2.5 acres)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.107	0.226	-0.135	-0.018	0.02	-0.004
	(0.085)	(0.144)	(0.155)	(0.129)	(0.242)	(0.208)
Lagged Cumulative Adoption (other group)		0.083	0.262		-0.125	-0.127
		(0.118)	(0.170)		(0.134)	(0.254)
Observations	571	237	292	571	237	292
R-squared	0.13	0.14	0.13	0.04	0.14	0.07
Num of hhold I.D.				329	147	169

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table C.2: Within and Cross Group Influences for Households With Below and Above 4 Acres of Land Holding

	Pooled OLS			Fixed Effects		
	All households	Smaller Landholders (<4 acres)	Larger landholders (>=4 acres)	All households	Smaller Landholders (<4 acres)	Larger landholders (>=4 acres)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.147	0.228	-0.208	0.026	0.054	0.138
	(0.085)*	(0.149)	(0.165)	(0.133)	(0.275)	(0.234)
Lagged Cumulative Adoption (other group)		0.019	0.32		-0.172	-0.296
		(0.117)	(0.174)*		(0.147)	(0.290)
Observations	571	247	255	571	247	255
R-squared	0.13	0.12	0.12	0.04	0.1	0.1
Num of hhold I.D.				329	153	147

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table C.3: Within and Cross Group Influences for Households With Below and Above 7.5 Acres of Land Holding

	Pooled OLS			Fixed Effects		
	All households	Smaller Landholders (<7.5 acres)	Larger landholders (>=7.5 acres)	All households	Smaller Landholders (<7.5 acres)	Larger landholders (>=7.5 acres)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.073	0.124	-0.144	-0.116	-0.209	-0.087
	(0.085)	(0.140)	(0.151)	(0.128)	(0.213)	(0.231)
Lagged Cumulative Adoption (other group)		0.027	0.214		-0.072	0.199
		(0.100)	(0.198)		(0.124)	(0.355)
Observations	571	336	167	571	336	167
R-squared	0.13	0.08	0.23	0.05	0.07	0.1
Num of hhold I.D.				329	198	98

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table C.4: Within and Cross Group Influences for Households With Below and Above 25 Acres of Land Holding

	Pooled OLS			Fixed Effects		
	All households	Smaller Landholders (<25 acres)	Larger landholders (>=25 acres)	All households	Smaller Landholders (<25 acres)	Larger landholders (>=25 acres)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.118	0.242	-0.115	-0.017	-0.004	0.434
	(0.088)	(0.160)	(0.267)	(0.134)	(0.255)	(0.194)*
Lagged Cumulative Adoption (other group)		-0.055	-0.072		-0.029	-0.223
		(0.079)	(0.256)		(0.115)	(0.237)
Observations	565	275	39	565	275	39
R-squared	0.13	0.15	0.53	0.04	0.1	0.78
Num of hhold I.D.				327	175	25

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

APPENDIX D: Within and Cross Group Estimates With Neighbors Specified by Education Groups

Table D.1: Within and Cross Group Influences for Households With or Without Formal Education

	Pooled OLS			Fixed Effects		
	All Households	Literate Households	Illiterate Households	All Households	Literate Households	Illiterate Households
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.079 (0.088)	0.066 (0.143)	-0.126 (0.179)	-0.088 (0.131)	-0.097 (0.201)	-0.09 (0.254)
Lagged Cumulative Adoption (other group)		0.038 (0.087)	0.191 (0.234)		0.018 (0.114)	-0.411 (0.309)
Observations	566	366	115	566	366	115
R-squared	0.12	0.14	0.17	0.04	0.03	0.15
Num of hhold I.D.				325	212	65

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table D.2: Within and Cross Group Influences for Households With Below and Above 5 Years of Formal Education

	Pooled OLS			Fixed Effects		
	All Households	Less Educated (< 5 years)	More Educated (>= 5 years)	All Households	Less Educated (< 5 years)	More Educated (>= 5 years)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.175 (0.088)**	0.119 (0.128)	0.153 (0.220)	-0.015 (0.129)	-0.054 (0.188)	0.144 (0.277)
Lagged Cumulative Adoption (other group)		0.01 (0.078)	0.036 (0.263)		-0.033 (0.098)	-0.426 (0.394)
Observations	565	390	87	565	390	87
R-squared	0.13	0.15	0.18	0.04	0.04	0.18
Num of hhold I.D.				325	224	50

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table D.3: Within and Cross Group Influences for Households With Below and Above 8 Years of Formal Education

	Pooled OLS			Fixed Effects		
	All Households	Less Educated (< 8 years)	More Educated (>= 8 years)	All Households	Less Educated (< 8 years)	More Educated (>= 8 years)
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Cumulative Adoption (own group)	0.11	0.118	-0.259	-0.143	0.011	-0.393
	(0.092)	(0.140)	(0.216)	(0.147)	(0.210)	(0.362)
Lagged Cumulative Adoption (other group)		0.032	0.266		-0.058	-0.219
		(0.066)	(0.387)		(0.102)	(0.569)
Observations	561	353	35	561	353	35
R-squared	0.13	0.12	0.67	0.05	0.05	0.71
Num of hhold I.D.				324	211	22

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

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Vita

Umar Serajuddin, son of Drs. Asma and Alamgir Serajuddin, was born in Lahore, Pakistan on April 11, 1972 after the separation of Bangladesh (formerly East Pakistan) from Pakistan (formerly West Pakistan). Due to the lack of diplomatic ties at that time between Bangladesh and Pakistan, Umar spent the first two years of his life in Pakistan separated from his father who was in Bangladesh. The family was reunited in London, England in 1974 where they spent 15 months while Dr. Alamgir Serajuddin completed a Commonwealth Post-doc fellowship. At the age of three, Umar returned to Chittagong, Bangladesh with both his parents where he spent the next 17 years prior to leaving for college in the United States.

Umar grew up in the Chittagong University campus where his parents had joined as faculty in the Department of History. After finishing high school from the Chittagong University School, Umar entered Middlebury College in Vermont where he received a Bachelor of Arts degree (*Summa Cum Laude*) in 1996 with a major in economics and a concentration in mathematics. After graduation, Umar worked at the Grameen Bank Replication Program in Dhaka, Bangladesh as a Policy Analyst. He then attended the University of Maryland, College Park, receiving a Master of Arts degree in economics in 1999. Following which, Umar joined the Ph.D. program at the Lyndon B. Johnson School of Public Affairs, University of Texas at Austin in 1999. During the completion of his Ph.D. curriculum, Umar also worked on poverty, rural development, and microfinance related issues at the World Bank as a short-term consultant.

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