Innovation Learning and Adoption:

Network Effects and the Case of Integrated Pest Management in Jamaica

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Abstract

There has been little analysis of the influence of network effects on agricultural technology adoption using primary data. This study uses primary data from Jamaica to understand the external (extension and developing agency training) and internal (inter- and intra-community learning) influences on adoption and learning about Integrated Pest Management of sweet potatoes. A mixed methods approach is used, with a quantitative focus. The principal strategy for identifying network effects is to differentiate individual and social influences. In order to do this, the empirical analysis was divided into estimations regarding individual and network influence. This creates a clear comparison for determining the significance of the network estimation. The main finding from the individual analysis was that export market access is very significant to learning and adoption of IPM in this context. This is an important finding because the purpose of the government's training program was to improve crop quality to increase foreign sales. Most importantly, it showed that the innovation is effective which is often difficult to discern in adoption studies.

For the network analysis a number of novel approaches were taken through the design of the network boundary, behavioural direction, identifying social structures and determining knowledge levels. Using dyadic and network autoregressive methods, the influences of network formation were estimated as well as the significance of networks on learning and adoption. The results indicated that network effects are significant to learning due to their ability to reinforce information, as opposed to adoption where observability or spatial effects are the dominant influences. This means that what causes one to learn or adopt differs according to social effects. Learning requires one to have consistent support in order to have learned, whereas adoption does not need consistent reinforcement to adopt as choosing the behaviour does not necessitate competency but only motivation of application. Thus, what compels behavioural change is the complexity of the behaviour. Since learning in this case is substantially more complicated than adoption, social capital provides the necessary support. In contrast, innovation adoption can be instigated simply and does not need practice or training, in this case; observing someone close by adopting an innovation can inspire a farmer to do the same. Network effects are more relevant to learning than to adoption, since to achieve competence when learning something, one has to practice and to make greater effort than for adoption.

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2SLS	Two Stage Least Squares
ABIS	Agricultural Business Information System
ABS	Absolute Value
AR	Autoregressive
ASSP	Agricultural Support Services Project
CARDI	Caribbean Agricultural Research and Development Institute
CGAIR	Consultative Group on Agricultural International Research
CRSP	Collaborative Research Support Program
CSPC	Christiana Sweet Potato Cooperative
GIS	Geographical Information System
HYV	High Yielding Variety
IDB	Inter-American Development Bank
iid	Independently and Identically Distributed
IMR	Inverse Mills Ratio
IPM	Integrated Pest Management
IV	Instrumental Variable
JAS	Jamaica Agricultural Society
JMOA	Jamaica Ministry of Agriculture
LSMS	Living Standards Measurement Study
NPV	Net Present Value
OLS	Ordinary Least Squares
PMO	Producer Marketing Organization
RADA	Rural Agricultural Development Agency
RCA	Rotating Credit Association
SAR	Spatial Autoregressive
SRI	System of Rice Intensification
SWP	Sweet Potato
USAID	United States Agency for International Development

VIF	Variable Inflation Factor
WUA	Water Users Association

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CHAPTER 1

Introduction

1. Introduction

The adoption of agricultural innovations is one of the primary focuses of agricultural development. For example, the world's premier pro-poor agricultural research collaboration, the Consultative Group on Agricultural International Research (CGIAR), spent $458 million to fund its 2006 research efforts (CGIAR 2006, p.3). This amount is only a fraction of the billions of dollars spent annually on agricultural technology research by both the private and public sectors. Since many households in the developing world depend on agriculture for their livelihoods, such research could be vital in increasing their productivity and hence prospectively their incomes. The World Bank 2008 World Development Report indicated that 2.5 billion households are engaged in agriculture and that 883 million of those households are considered poor (World Bank 2008, p.3). Given this level of rural poverty, understanding how to properly implement agricultural technologies could be significant in increasing rural welfare.

Agricultural extension is a particularly expensive activity for developing countries. As compared with developed countries, extension activity in developing countries is inherently more expensive because of the substantially greater constraints and variation among their farming populations (Feder, Just and Zilberman, 1985). Any effort that reduces the cost and increases the efficacy in diffusing innovations should merit significant attention.

In order to effectively introduce a technology into an area, numerous factors must be considered. These include agro-climatic, physical, economic, health, socio-economic, education, tenure, credit and infrastructure characteristics of farmers and communities, which have all received thorough analysis in the literature (Feder and Umali, 1993). However, social behaviour has yet to receive the attention it deserves. Although it may seem that social behaviour or social effects[1] would be trivial compared with something such as water, it could be central to adoption (Feder and Savastano, 2006). This study deals with three main aspects of social behaviour – social learning, reference groups and networks – to understand the influence of social behaviour on the innovation process. Social learning regarding innovation adoption concerns the learning of new knowledge from other farmers within the community (Munshi, 2004). Reference groups concern immediate social interactions of people connected through an organizational norm (Fafchamps, 2004). Social networks reflect organizations dependent on social structure characteristics (individual links, position and clusters in this study) (Wasserman and Faust, 1994). The intention of this study, using an economic analysis, is to further the understanding of the relationships of these phenomena to agricultural adoption, using primary data.

[1] This term will be used interchangeably with social behaviour

Specifically, I will be estimating the influence of learning and non-learning reference groups (normative interactions) and networks (social structures) on agricultural adoption. Social learning is important to adoption because it concerns information transmission. It is assumed that information acquisition is significant to successfully adopting an innovation because it reduces the uncertainty in applying it. Reference groups and networks are chosen as the social entities for analysis because they have established data collection and estimation methods.

Among other factors, social interactions probably influence innovation diffusion. Identifying social channels through which innovations diffuse among farmers can reduce costs by increasing efficiency. If a population's reference groups and network structures with respect to adoption are identified, then a more efficient strategy for the introduction of technology can be designed. Those who are inclined to share technologies are expected to do so more carefully and over a longer period than extension agents (Feder and Savastano, 2006). This is particularly important in the case of complex innovations such as IPM, which require substantial time for training to be successfully implemented (Feder, Murgai and Quizon, 2003).

Although there is increasing activity in this area of research there are only a few directly relevant empirical works (Bandiera and Rasul, 2006; Conley and Udry, 2010; Van den Broeck and Dercon, 2011). These three works use primary data to analyse the influence of social networks on innovation adoption. All these papers took different paths with regards to data collection and estimation. Bandiera and Rasul (2006) use a random sample of household heads, from several villages, and fixed effects to control for village level effects. Sunflower seed is the innovation of interest. It was found that kinship is very significant to adoption and that herding effects may be more complex than once thought. The other significant network is friendship. These results support the strength of the position on ties which argues that more socially significant ties will be more influential in behavioural choice. The estimation indicated that when many people have adopted an innovation, the remaining farmers strategically delay to reduce uncertainty. Furthermore, the delay length has a non-linear relationship with peer adoption wherein delay increases with the number of adopters, then reaches a threshold wherein there is a respective decline in the group effect. There are concerns regarding data collection, as it is unclear how a social interaction boundary was defined. Also the actor and location choice for the observations was not clearly explained. The better defined and simpler the interaction area, the greater the probability of the data being viable. My study differs from this, as its focus is on knowledge and adoption and it is concentrated in a single location.

Conley and Udry (2010) focus on the other aspect of the thesis, learning. Their study uses a sample of villages, as in Bandiera and Rasul (2006), but uses households for observation. Concerns in this study provided insight into my design. The Rural Agricultural Development Agency (RADA) noted, like many in the literature, that experience is significant to inducing adoption and learning. The reasoning is that those more invested and committed to an activity will take the time and initiative to engage in it. However, experience may also be detrimental, as veteran farmers can be less keen on innovation due to confidence in their superior knowledge. This can lead to networks being fuelled by novices, as they are eager for information. It is believed that less experienced

farmers are more likely to adopt and learn because of this. Another insight drawn from this work is the significance of spatial and temporal correlations. Space can be a strong correlate with network effects in rural areas because of poor transportation, infrastructure and distance to other municipalities. Spatial correlation must be controlled for, as network effects can be assumed to be significant when it is only a spatial effect.

The paper that provided true insight regarding data collection was Van den Broeck and Dercon (2011). A household level village census was performed, which provides a clearly defined interaction area and alleviates the possibility of spurious interactions. As in the previous studies, strength of ties is very significant, with family being the most significant network. One of the problems that was identified here and in the Conley and Udry work is that proxies such as productivity are used for learning. This makes the assumption that if a farmer is competent in the innovation then they will be more productive. There are many reasons why this might be true (agronomic, other innovations, disadoption, etc.) This led me to develop a knowledge test, in order to capture innovation competency directly. The issue of intra-household information pooling was another problem that I sought to solve. In two of the given studies authors use households as the observation. If households are used in network studies, however, intra-household information pooling has to be assumed and this is highly unlikely as people do not inform the household of all their interactions. This led me to use individual farmers with independent farm economies as observations.

Below I discuss the significant areas that influence this study: Integrated Pest Management (IPM), Research and Development, and Extension. The intention is to introduce the depth of the issue and further concerns.

IPM was developed to create an environmentally appropriate method for pest management. The key word in IPM is management because the purpose is not to eradicate pests but to manage them at a level that ensures the crop's and environment's viability. What is different about IPM is that it is a technology based on principles rather than technique. The objective is to apply a set of techniques predicated on these principles that maintains the health of the environment. These techniques often consist of monitoring, cultural, and biological practices that result in the reduction of pesticide use. Hence, there is not a 'common' set of methods as each IPM regime is dependent on the crop and the area's respective agro-ecology. This is what makes it particularly sophisticated and complex as it is heavily knowledge and information driven. Without having a strong understanding of crop, pest and agro-ecological history it is difficult to develop an effective IPM regime.. Although it has been a part of the government's research and development program[2] since the early 1990s, IPM is not a common technique in Jamaica as there is a strong culture of pesticide use. In Jamaica the IPM techniques that are commonly promoted are field monitoring, field sanitation, selective planting material adoption, and crop rotation, but again each circumstance is different.

IPM is a special technology, in that it can be used strategically to implement partial adoption. Partial adoption can even be more effective than full adoption, as the innovation is most effective when the methods are tailored to the needs of each crop. This means that

[2] This research supported by the United States IPM Collaborative Research Support Program (CRSP)

the training needs to be similarly malleable to facilitate its strategic application. Gilbert et al. (2008) discuss the need for compartmentalizing the methods within IPM 'packages' for its application. Rather than taking the view of IPM being strictly a complex technology with multiple methods, they highlight the fact that often an entire IPM 'package' is not applied but only certain methods suitable for the farmer's crop. In order to aid its implementation, extension must represent the innovation's flexibility by tailoring training methods to the respective types of application of the IPM 'package'. This ensures cost-effectiveness. Other papers such as van den Berg and Jiggins (2007) demonstrate that IPM should be disseminated through farmer field schools because their thoroughness and length are able to entrench its complex ideas. Moreover, they are able to aid the development of durable social links that disseminate information. This supports my argument for integrating farmer networks into extension. Since it is recognized that the most effective training method involves extensive interaction, this indicates the importance of immersive dissemination methods. Hence, targeting social networks represents this characterization.

What is notable about IPM is that it is often difficult to teach effectively and for farmers to implement. This is due to its complexity and its unique application to each crop. Because of this, the farmers must understand not only the methods but also the agro-ecological issues that underpin them, in order to apply methodological variations appropriately.

Many issues influence IPM adoption. Since it is an innovation that is knowledge-intensive, complex and often requires exceptional labour, it can be difficult to persuade farmers to adopt it unless it is uniquely fitting. Moreover it is often only suitable for cash crops (Orr, 2003). The effort that is exerted for its adoption and implementation requires substantial returns as it may be too exotic for poor and uneducated farmers (Mahmoud and Shively, 2004). Thus there must be a sufficient incentive, whether market, health or culture driven. Reassurance from peers, such as well respected network peers targeted for training, can also be helpful. Other concerns involve limiting any disturbance to the standing cropping systems (Reichelderfer and Bottrell, 1985). Also, it is important to have a strong knowledge of the target group's perceptions of pest issues and influences as well as their history with agricultural training. Aside from economic factors, psychological and sociological concerns are also significant.

In general it can be difficult to incentivize IPM training because of its sophistication. It is possible that subsidies or guaranteed market access would have to be used to encourage farmers to adopt. This is particularly applicable for situations where adoption is necessary for a community's welfare. High costs of alternative pest management methods such as insecticide could also induce adoption. However, in order to know how to effectively introduce IPM it is important to know the most fitting IPM system for that context. Methods such as the establishment of experiments, although costly, can be highly effective for pinpointing the agro-ecological issues and the precisely needed methods (Way and van Emden, 2000).

The central pillar in the innovation process is research and development. Agricultural research in low-income countries has predominately been based on research from the CGIAR research centres (Clark, 2002). There has been a particularly hierarchical

innovation process wherein research from CGIAR centres is adapted in national research centres for local adoption. In addition, research has often been politically motivated and focused on endowed farmers rather than poverty reduction. This lack of welfare-focused innovation development contributed to persistent poverty. Innovation systems are often designed to offer clear and simple solutions such as increasing crop yields rather than to solve complex problems that involve social, economic and agronomic systems (Hall and Clark, 2010). As problems often require attention to the complex interaction of these factors, this change of viewpoint is needed. Le Gal, Dugue, Faure and Novak (2011) illustrate that there are two general research approaches 'Design' and 'Design Support'. The former entails a hierarchical and detached approach, wherein the farmer is not integrated into the innovation process, and is expected to implement innovations without providing any input. This process is often employed. However, farmer-integrated ('Design Support') approaches are viewed as having substantial benefits because they correct the information asymmetry that occurs when farmer-assistance is absent. This helps ensure that the innovation is suitable for the end user, which also aids cost effectiveness. I believe that the optimization of innovation production systems can substantially contribute to increasing rural welfare levels.

Traxler and Byerlee (2001) show how research is significant to farmer returns, most notably how important efficiency and efficacy is to innovation systems. Integrated processes like those presented by Le Gal et al. increase the likelihood of innovation applicability and significant rates of return. This furthers support for my own initiative for developing extension systems that are not only as efficient and effective as possible, but also as resilient and progressive (Hall and Clark, 2010).

Another perspective on increasing the effectiveness of innovation systems is Sumberg (2005). A primary argument here is that innovations systems should be focused on design, not on research. Hence, the initial concentration should be on the creation of a plan for strategic innovation. Research can often be performed for the sake of science or ego; creating a plan for strategic innovation will lead to research tailored to empirical application. This lessens the possibility of research becoming elitist, politically motivated or useless. The importance of creating more effective innovation systems is highlighted by Alene and Coulibaly (2009) whose estimates indicate that research has high rates of return wherein millions of people are lifted out of poverty, particularly with regard to Consultative Group on Agricultural International Research (CGAIR) research. Improving on these returns should be the focus; and the only way to do this is to design more effective innovation systems. Providing innovations such as network integration in the dissemination process could further this poverty-reducing effort.

Innovation and technology system design are only empirically significant if they are effectively implemented. For this a suitable extension system has to be developed. In this thesis, I intend to illustrate the significance of network integration in extension systems. There are a number of reasons for this. Pretty (2003), and Pretty and Smith (2004) illustrate that social capital characteristics such as trust and cooperation enable dissemination, reduce free-riding and encourage individual investment. These characteristics make network integration advantageous. Targeting social structures for innovation dissemination and learning could have substantial efficiency benefits, because

extension will free-ride on natural innovation networks. Furthermore, by designing training to facilitate one-to-many relationships (Klerkx and Gildemacher, 2012) substantial gains in cost-effectiveness can be realized. Although my objective is to determine the positive significance of social networks, these linkages can also have negative effects. Identifying these effects is important, as they hinder the dissemination process. Often authors do not discuss these effects, but this is going to be a significant part of the empirical analysis in this work. If extension officers can be warned of those that are unlikely to diffuse, then this may substantially improve the rate of diffusion, thereby reducing training visits and required resources.

Steyaert and Jiggins (2007) define learning as 'the epistemic work that is done as a part of action or practice'. This epistemic work is central to application because without knowledge and competency, an innovation has little value. Hence, designing a system that fosters learning is very important to ensuring effective implementation. Mierlo, Leeuwis, Smits and Klein Woolthuis (2010) indicate the main failures of innovation systems. Two of these concerns are the efficacy of interactions and strategic intelligence. I seek to investigate these using network analysis. By understanding the structural characteristics of farmer networks as well as their knowledge, one can discern how to strategically implement farmer training to alleviate these concerns.

Another note is the development of flexible and adaptive innovation systems. Klerkx, Aarts and Leeuwis (2010) highlight the importance of designing adaptive innovation systems that tailor services to recipients. The use of networks would certainly enable this quality, as training would be fitted to social characteristics.

There are a few common training methods. The two most common are training and visit, and farmer field schools (Birner and Anderson, 2007). The former was the first major transformation in extension for developing countries, and it gained its prominence in the 1970s (Feder et al., 1986). This extension system focuses on a target group of contact farmers who are expected to diffuse the information to the remaining non-contact farmers (Feder et al., 1986). This often causes bias, such as by prioritizing interaction with wealthy or influential farmers (Feder et al., 1986) hence skewing assistance towards the wealthy. This is one of the reasons for pursuing this study. Identifying social networks and structures can help to reduce bias by determining who receives excessive support and those that promote collusion.

The second extension method, farmer field schools, followed training and visit extension in the 1980s (Feder et al., 2003). It helped reduce targeting bias and is particularly applicable for complex innovations such as IPM (Feder et al., 2003; Feder et al., 2004). This method involves the establishment of a participatory training schedule that immerses farmers in the technology. In general the results were promising but there are still concerns with farmer-to-farmer information transfer (Feder et al., 2004). Thus again the use of networks could enable trainers to target the farmers that would most effectively diffuse information to their respective communities.

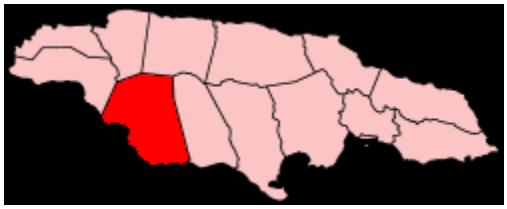
This research is important for the policy debate because it looks at issues regarding agricultural extension. It seeks to help Jamaica's extension agency, RADA, to understand the influence of social effects on technology diffusion in relation to extension. RADA is

considerably resource-constrained, hence additional knowledge that increases efficiency is welcomed. Their current training strategy utilizes training and visit, plot demonstrations and farmer field schools. The empirical analysis will be completed on a farming community in the Parish of St. Elizabeth that has been imparted IPM by RADA.

This chapter will provide an empirical and conceptual background as well as reviewing the thesis objectives. First I will present an overview of the study area, then an analytical framework to give a conceptual understanding of networks, learning and adoption. I will conclude with the objectives and how the study is significant to the policy arena.

1.1 Study Area

Jamaica is a small mountainous tropical island in the Caribbean, highly prone to hurricanes. The economy is supported primarily by tourism, followed by bauxite mining (Thomson, 2011). It is a parliamentary democracy dominated by two parties spawned by the labour movements of the early twentieth century. Historically, the most important crop in Jamaica is sugar, as it was a British slave colony. Since independence the sugar industry has declined greatly. Currently, the most significant crop is coffee as it is a high value commodity. The parish[3] in which the study is conducted is St. Elizabeth. This is one of the most significant parishes for agriculture in Jamaica. It has been deemed to have some of the most fertile soil on the island. It also has the highest number of farmers, by parish (ABIS, 2012). It is a primary producer of fruits and vegetables. It also produces a substantial amount of sugar. St. Elizabeth's main agricultural difference from other parishes is that it produces a wide range of crops. There are several parishes that concentrate on producing one commodity such as banana, coffee or livestock, but St. Elizabeth is distinguished by being dominated by mixed small farms. It is located in the south-western portion of the island and has a population of 146, 404 (based on the 2001 census).



The farming community of Hounslow is in a valley next to the Santa Cruz Mountain Range and has about 100 adult sweet potato farmers. The small sample size and community density was needed to reduce attrition and time due to the length of the social network survey. The main crops for which IPM has been imparted are sweet potato, sweet pepper and hot pepper. Of those three, sweet potato is dominant and the study's focus. In general, the farming community has similar farm sizes, agronomic characteristics and crop

[3] Highest administrative level

mixes. It is historically one of the most prominent farming communities in the Caribbean as it has a history of leadership in the application of innovations. Essentially, this area has some of the best agricultural characteristics (e.g. flat, irrigated, nutrient-rich soil) and is in the most productive and diverse parish for agriculture; thus it came to be a government model for displaying new technologies. In addition, it is one of the country's largest areas for the cultivation of marijuana.

Agriculture is the primary livelihood for the study area, as 88% of farmers in the census noted farming as their primary income. Sweet potato is second only to groundnut in its significance for farmers.[4] Since sweet potato has only become commercially viable in the past 10 years, the crop has rapidly become prominent, as the area had been dominated by groundnut and pumpkin for over 50 years. In addition to these crops a very significant income source is marijuana cultivation. This is by far the most lucrative and is widespread. Although the returns for this activity are exceptional, because of its inherent risk most farmers are equally committed to legal livelihoods. This means that marijuana planting does not necessarily discourage sweet potato farming.

IPM was introduced by RADA through two methods. A pilot introduction was done in 1998, then it was fully initiated in 2003.[5] First, targeted farmers were used as demonstrators for the surrounding farmers.[6] These were farmers who had experience with IPM. Second, independent demonstration plots were established for all interested farmers.[7] These were managed jointly by the farmer and extension officers. Preliminary analysis by RADA has shown that there are three types of adopters. First, there are those who adopt all elements of IPM. Second, there are those that adopt some techniques. Lastly, there are those that adopt none. RADA assumes the reasons behind these differences in adoption are wealth, age and education. Thus, the wealthier, younger and more educated farmers adopt more, and the poorer, older and less educated adopt less. It has been indicated by RADA that there is evidence of informal groups among the farmers, thus some groups should be readily identifiable. However, RADA is unsure how these groups are formed and whether they are influential in IPM's dissemination. In general RADA has acknowledged that farmers are open to sharing information with one another, although how they share information is uncertain.

Sweet potato itself has only been promoted as a cash crop since the inception of the RADA IPM program that was initiated in 2003. The purpose of the IPM program was to develop sweet potato as an export crop as it was determined to have significant market potential. Hence, IPM and sweet potato as an export crop were promoted jointly. Prior to this period sweet potato was only significant in the domestic market but was not a major crop for small farmers, particularly for those in the research area. Moreover, this was the first sweet potato training program implemented by RADA.

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[4] 25% of farmers noted sweet potato as their most important crop compared with 42% for groundnut
[5] I was informed of this during an in-depth interview of one of the extension officers.
[6] As note 4.
[7] As note 4.

Although RADA is in general the main training source for farmers,[8] the most significant training source for IPM and sweet potato is the farming group formed by Agricultural Support Services Project (ASSP), a marketing and training program started in 2003 by the Inter-American Development Bank (IDB). Beginning in 2003, this project promoted the sweet potato and trained farmers in IPM. It provided market support and exceptional training resources in order to give farmers the necessary aid to increase their incomes. In addition, the farmers planted on adjacent plots. ASSP membership is of particular interest in the network analysis. The group was composed of about 10 farmers at a time and had a management structure that was created by the farmers with the support of a government consultant. In addition the focus was on giving the farmers the power of the group by allowing them to elect their own management committee, to give them the ability to define their own needs. However, there were many questions over the formation of the groups in terms of the membership process, such as negligence in ensuring that it was fair, open and competitive. This is significant because it means that there was bias in the selection, thus information dissemination from group members would not be as effective as with a balance of actors. Hence the group would not be as influential in affecting the behaviour of others.

1.2 Analytical Framework

For a theoretical understanding of adoption, social interactions and learning, a Bayesian updating framework is given, based on Berger (1985). Bayesian updating is a common tool for modelling learning in agricultural adoption. It is used because it accounts for the dynamic and subjective learning process by capturing the influences of previous states of being on observed knowledge. Bayesian updating is based on the idea that adherence to a new event is subjective. This is due to the belief that the current probability of an event is dependent on prior information regarding that probability, meaning that the current probability (likelihood) and the prior probability are combined to create the subjective posterior probability. In accordance with the identification of this model, beliefs will be used in substitute for probabilities. The models show the key relationships in the information updating process for Bayesian farmers within their information groups. Two theoretical models are presented from Van den Broeck and Dercon (2007): social learning effects and adoption; and social learning test. I will address them in their given order.

Two forms of the former model are presented, a perfect and imperfect information model. The perfect information model works on the basis that the social information is true, i.e. that there is no error in its quality. The central focus of the imperfect model is the noise in the belief of the social information, or social trust.

The main assumption of the model is that the expected production increase from the technology is not a sufficient incentive for adoption (Van den Broeck and Dercon 2007, p.11). This is due to the observation of the lack of adoption after farmers have been introduced to an innovation. This is an important assumption because it means that there

[8] There are other trainers such as through USAID, Bodles Agricultural Research Station, ASSP and other project consultants, but they are insignificant compared to RADA

are other significant factors impeding adoption, which are the trust of social information and the influence of the belief of the adoption benefit of one's reference group in this model.

For both models the information updating criterion is the technology's expected benefit. Two assumptions of the model are that the variance σ^2 of the Independently and Identically Distributed (*iid)* distribution of the true benefit of the innovation is known to all farmers, but not the mean $\beta_t(x)$. Thus, the expected benefit of the innovation is unknown. Information updating is dependent on the relationship between the expected benefit $\beta_t(x)$ and the observed variance of farmer *i* accounting for the prior belief of the expected benefit of farmer *i,* as well as the prior variance of farmer *i* accounting for the mean benefit of his reference group's adoption behaviour. The prior beliefs in this case are the perceived benefits of the innovation in a state lacking the current information. In addition, there are two types of priors: individual and social. The current beliefs are those beliefs that are held in the period after the prior beliefs. Updating occurs when the expected benefit is positive and will not occur if it is less than or equal to the combined current and prior beliefs of the farmer's technology benefit variance. This means that for updating to occur the expected benefit must exceed the believed risk in the innovation's benefit.

Figure 1: Perfect Information Model

(1)
$$\beta_t(x) = \frac{\frac{\sigma^2}{n}}{\tau_{t-1}^2 + \frac{\sigma^2}{n}} \beta_{t-1} + \frac{\tau_{t-1}^2}{\tau_{t-1}^2 + \frac{\sigma^2}{n}} \bar{x}_t$$

$\frac{\frac{\sigma^2}{n}}{\tau_{t-1}^2 + \frac{\sigma^2}{n}} \beta_{t-1}$ = Belief of the observed variance of farmer *i* of the innovation's expected benefit with respect to the prior expected benefit of farmer *i*

$\frac{\tau_{t-1}^2}{\tau_{t-1}^2 + \frac{\sigma^2}{n}} \bar{x}_t$ = Belief of the prior variance of farmer *i* of the innovation's expected benefit with respect to the expected benefit of the experimenting farmers of his reference group

(Van den Broeck and Dercon 2007, p.12)

i = farmer (1,…..,*i*)

x = true benefit of a technique

σ^2 = farmer *i* variance of the observed belief of the innovation's true benefit

t = time

τ_{t-1}^2 = farmer *i* variance of the prior belief of the innovation's true benefit

n = # of farmers

$\overline{x_t}$ = mean benefit observed at time t of n experimenting farmers in reference group

$\beta_t(x)$ = posterior expected true benefit of the innovation

β_{t-1} = farmer *i* expected prior belief of innovation's benefit

The difference between the perfect and imperfect models is that the imperfect information model has a social trust term. This represents the social trust in social information flows. Instead of assuming the learning externality as constant, as in the perfect information model, it is stated that it can vary. This means that there is uncertainty in the information of other farmers. In this case if the variance δ_k^2 (social trust term) in the learning externality is non-zero, then updating of the prior beliefs will be slower because of the uncertainty, meaning that the variance in the learning externality is positively related with the information acquisition time. Thus, the prior will be less likely to be updated due to excessive noise in the social learning process. Furthermore, the variance level in the learning externality determines the amount of trust in the social information. This means that if the variance is zero then the farmer has complete trust in the information of other farmers, but if the variance is infinity then there is none. Moreover, the higher the risk in applying the information, the less likely that it would be used to update a farmer's prior beliefs. In this case, if there is more risk then it is less likely that the farmer will adopt because there is less trust in the information's source. Hence, risk determines the learning process for adoption. Notably, this goes back to the main assumption that uncertainty in acquiring social information is a primary adoption determinant.

Figure 2: Imperfect Information Model

(2)

$$\beta_t(x) = \frac{\frac{\sigma^2}{n}}{\tau_{t-1}^2 + \frac{\sigma^2 + \delta_k^2}{n}} \beta_{t-1} + \frac{\tau_{t-1}^2}{\tau_{t-1}^2 + \frac{\sigma^2 + \delta_k^2}{n}} \overline{x_t}$$

$\beta_t(x)$ = posterior expected true benefit of the innovation

δ_k^2 = Variance of the noise (trust) in the information regarding the innovation's benefit

$\frac{\frac{\sigma^2}{n}}{\tau_{t-1}^2 + \frac{\sigma^2 + \delta_k^2}{n}} \beta_{t-1}$ = Belief of the observed variance of farmer *i* of the innovation's expected benefit with respect to the prior expected benefit of farmer *i*, including the social trust term δ_k^2

$\frac{\tau_{t-1}^2}{\tau_{t-1}^2 + \frac{\sigma^2 + \delta_k^2}{n}} \bar{x}_t$ = Belief of the prior variance of farmer *i* of the innovation's expected benefit with respect to the expected benefit of the experimenting farmers of his reference group, including the social trust term δ_k^2

(Van den Broeck and Dercon 2007, p.13)

Social Learning Test Model

The social learning test model is premised on the work of Foster and Rosenzweig (1995). Basically, it states that learning only occurs when there is an increase in productivity. First an individual learning model represented by a Bayesian production function is given, wherein current yield is a function of the prior farm characteristics and the farmer's prior beliefs of the benefit of adoption.

Figure 3: Individual Learning Test Production Model

(3) $$Y_{i,t+1} = f(Z_{i,t}, \beta_{i,t})$$

i = farmer, (1,…..,i)

t = time

$Y_{i,t+1}$ = output of farmer i in period $t+1$

$Z_{i,t}$ = prior individual farm characteristics

$\beta_{i,t}$ = prior belief of benefit of applying innovation

(Van den Broeck and Dercon 2007, p.14)

However, for the social learning model the individual prior belief for the benefit of the technology is assumed to be constant. This assumption is made because what is of interest

is the influence of the network members' prior beliefs on productivity. The individual prior belief of the previous production function is replaced with the network members' mean prior beliefs.

Figure 4: Social Learning Test Production Model

(4) $$Y_{i,t+1} = f(Z_{i,t}, \overline{X}_{-i,t})$$

$\overline{X}_{-i,t}$ = mean prior belief for reference group members of benefit of applying innovation

(Foster and Rosenzweig, 1995)

1.3 Conclusion

Learning is a central aspect of adoption. This is particularly so for this IPM technology because it necessitates a substantial level of skill to be properly implemented, as noted by a senior plant scientist at RADA (Feder, Murgai and Quizon, 2003). In order to understand how skills are developed within a community it is important to know the networks and groups through whom information is funnelled (Munshi, 2004). If these social entities can be identified then they can be targeted when the technology is introduced, which will increase the adoption rate and reduce the strain on extension services. Furthermore, within social learning groups the depth and precision of the technology's implementation will be greater due to the concentration of adoption among those that are eager to share information. This objective also regards non-learning groups. In this situation farmers are only imitating (observability) each other and learning is absent. Spatial neighbourhoods would most probably be the primary reason for IPM imitation, since it is commonplace for farmers to take note of the planting methods of neighbours.

The purpose of this study is to investigate how adoption and learning are influenced by farmers' network interactions, by comparing their estimations with their respective network econometric analysis. Concentrating solely on farmers' social behaviour permits the understanding of how behavioural choice is determined by a farmer's social environment i.e. social reference groups and networks. This is important because it analyses how forces outside of the extension service effects technology. Furthermore, a comparison is provided with extension in order to understand the significance of informal training as compared with extension. Also, since there is no explicit cost to the government in this diffusion process, the extension agency acts as a free rider to socially induced diffusion. This reduction in costs is particularly important to developing countries because of their insufficient resources for agricultural technology and training services. In addition, this is a main concern of RADA since its resources are insufficient for the needs of the country.

This final objective gives the study a policy focus. Since this study was conducted under the support of the Jamaica Ministry of Agriculture (JMOA) and specifically the extension agency, the policy implications of the results are of the utmost concern. All the results and analysis will concentrate substantially on the implications for the extension agency's training and technology policy. Moreover, a prime focus will be on finding ways that reduce costs and increase efficacy for RADA because of its resource constraints.

The thesis is structured in the following way. The introduction is followed by the literature review in Chapter 2 and then an extensive description of the data generation process in Chapter 3. Following these chapters is the empirical analysis which begins with Chapters 4 and 5, adoption and learning respectively, analysing these two behaviours without network effects. The final empirical chapter is Chapter 6 on Networks, which is the most substantial section of the empirical analysis. The conclusion is presented in Chapter 7.

CHAPTER 2

Literature Review

2. Introduction

The objective of this chapter is to identify the pertinent influences on adoption and learning as well as to explore the influences of the respective social effects.

This review encompasses two sections. The purpose of Section 1 is to give a thorough analysis of agricultural adoption and its influential variables. This is meant providing a firm understanding of adoption to ensure that the social effect is being estimated precisely and that adoption is not being determined by an unobserved variable correlated with the social effect variable(s). Such analysis will reduce the potential bias and increase the efficiency of the estimation. Section 2 will review the literature specific to analysing social learning, interactions and networks. This section will be split into two further sub-sections: the first will discuss the empirical agricultural social behaviour literature; and the second will review the theoretical literature.

There is an overwhelming literature on agricultural adoption. Beginning with the seminal rural sociology work of Ryan and Gross (1943), and later Rogers (1962) the literature has grown into an extensive and seemingly ever-growing entity. Here, I will analyse an array of adoption influences. To begin, I will discuss the review paper by Feder and Umali (1993) to give a perspective on the literature.

2.1 Agricultural Adoption

Since this literature is vast, it is necessary to start this review with a survey in order to bring out some key aspects. The intention of Feder and Umali (1993) is to give a summary and brief analysis of the recent developments within the adoption literature in order to expose issues. Both theoretical works and empirical estimations are reviewed. No particular aspect of the literature is focused on; rather, myriad papers represent principal areas. Of the variables within the literature, farm size, tenure, education, credit, and risk characteristics are considered as the most pertinent. Another central aspect is the difference between dynamic and static models. The use of dynamic models is seen as the way forward. Dynamic modelling is ideal for studying learning since it is a dynamic process. One area that might be of particular importance is dynamic learning, through technological packages. As will be seen in Byerlee and Hesse de Polanco (1986), and Smale and Heisey (1993), packaged innovations are more complicated because there are a number of combinations that can be constructed from the model package. Moreover, empirically, this is a common type of innovation that is promoted by extension agencies. However, non-packaged technologies can also be adopted dynamically due to the inherent learning and adaptation process. Also discussed is the difference between aggregate and individual influences of diffusion. Aggregate diffusion studies analyse the adoption of

populations whereas individual diffusion studies analyse individual effects, such as this one.

The paper by Besley and Case (1993) is the leading work in contemporary technology adoption literature. In particular, it provides a clear structure for estimating agricultural adoption in developing countries. Instead of performing an estimation, the paper develops prospective empirical models. The beginning of the paper reviews the respective strengths and weaknesses of estimating time, cross-section and panel adoption datasets. The primary issue regarding these datasets is static versus dynamic analysis in adoption. Since adoption is a dynamic process it is noted as the preferred method. However, the controversy is that panel data must be used in order to properly capture the temporal influence as well as the numerous variables that determine adoption. Since panel data is rare, because of its necessary costs, it is uncommon to be able to conduct such estimations. The main development of the paper is that of a dynamic choice model wherein the dynamic adoption process is modelled based on a first-order Markov process. This model accounts for transitional states of learning or choice that adopters would logically go through until they reach Nash equilibrium or the *Markov perfect* state. Another innovation of this paper is the modelling of externality attractions. This looks at the influences of individual learning, market and network externalities on neighbouring farmers. This is important because each respective phenomenon could be significant in increasing the welfare of farmers as far as the innovation is concerned. The methods in this work are particularly relevant to estimating social behaviour in agricultural adoption because of the externalities model derivation that recognizes the importance of peer effects.

2.1.1 Learning by Doing

Intuitively, learning by doing occurs when a farmer modifies his production techniques or factors over time in order to increase productivity. This is particularly important for agricultural adoption among small farmers who, due to their significant resource constraints, are continuously fine-tuning their production process in order to receive the highest marginal return,. For learning by doing, Ghadim and Pannell (1999) develop a dynamic model for trialling a new crop. It is determined that, the farmer will decide on long-term adoption over several years of practice. Adoption does not occur when a farmer begins producing with a new technology, but only when the new technology becomes a permanent factor in the means of production. This is an innovative concept because it views individual adoption as dynamic and dependent on long-term use. Such a definition for adoption applies widely to crop farmers, because they often trial a new crop on a marginal piece of land for many cropping seasons before they make a substantial planting on their crop land.

Another issue is not only learning about the potential of a new technology, but also one's own ability in applying it. If it is discovered over time that the innovation is unsuitable to the farmer's skill set, then the innovation will be discarded and adoption will be improbable. However, if the farmer's skill set fits, they will able to rapidly develop competence in using the technology and the probability of adoption will be high. Also, it is determined that the entire purpose of the adoption process is to learn how to reduce the

risk and uncertainty of the new factor through experimentation. Furthermore, one of the primary conclusions is that trialling is meant to increase the expected value of the utility of the Net Present Value (NPV). A final interesting concept is that of an 'option value'. This looks at the delay in fully trialling a technology if there are significant fixed costs. The 'option value' is based on the risk and uncertainty in adopting a technology with significant fixed costs. Thus, learning is negatively related to the 'option value' because as learning increases and the farmer becomes more knowledgeable about the innovation, the incentive to delay the investment ('option value') decreases. All of these remaining points reflect a farmer's adoption process, wherein the primary objectives are to realize the highest utility of the NPV, minimize uncertainty, and strategically acquire fixed costs.

Another prominent work about learning by doing is Feder and Slade (1984). Their paper builds on a shortcoming of Kislev and Shchori-Bachrach's (1973) paper. The fault in the latter work is that the elements of knowledge in the model are not input-specific. Thus, only a general representation of knowledge is given. This work addresses this problem by compartmentalizing specific input knowledge in the production function. The centrepiece of this paper is to analyse the former issue dynamically. The model presented illustrates that farmers with more knowledge will adopt earlier and that production efficiency will increase over time due to experience. Another central point is that large farmers will adopt first because they would benefit more from adoption, since risk is more widely distributed and because they would have specialized production which would realize higher marginal profit than for small farmers.[9] Additionally, the marginal return of knowledge is significantly higher for large farms, since they can expend the same resources as the small farmer, but apply it to a much larger area of production.[10] This means that non-physical technologies, *ceteris paribus*, are scale-neutral and but not size-neutral. Furthermore, the seeking of innovation information is relative to farm size. In this case, large farms strongly seek information whereas exceptionally small farms do not seek information. All of these points are valid in real terms because small farms will certainly not seek technologies if they do not have the capacity for them as compared with large farms. Something that is novel in the model is that information acquisition is a function of price. This means that when price decreases, such as through price supports for the innovation, the information cost needed for adoption is lowered, enabling more farmers to adopt. This is certainly plausible, because when the price decreases more farms will purchase the innovation and the ability to acquire the information will increase.

One of the methods for modelling learning by doing is Bayesian. Jovanovic and Nyarko (1996) present an interesting theoretical framework using Bayesian methods to model the effect of social learning on production between agents, based on a simple two-choice scenario of innovation adoption. An assumption is made that the user of a technology will infinitely adopt if he is a dynamic agent. Also, if he is a static agent then he will always produce less than the dynamic agent because he never changes to a more productive technology, *ceteris paribus*. In a real setting there are certainly unforeseen events that would challenge unhindered adoption. If the markets are unstable and the farmers are poor, then the ability to continuously update technologies is virtually eliminated. In

[9] For scale-responsive technologies
[10] For size-responsive technologies

general the model is quite simple, in that it does not account for non-linearity within the adoption process or for possible structural breaks that could interrupt the asserted infinite adoption. Another assumption of the model is that there is a linear relationship between learning and productivity. An interesting, yet weak, assumption is of agents being myopic and maximizing production in each period. This is particularly unrepresentative of poor farmers, because they are constantly tailoring their production in each period to hedge against risks rather than maximizing production (Batz et al., 2003). Another interesting issue that the model accounts for is the constraint of human capital by different grades of technology. For each type of technology, a particular type of human capital is warranted. This recognizes the restriction in human capital on using certain technologies, which is a standard issue in technology diffusion.

2.1.2 Scale Effects

Adoption of agricultural technologies in the developing world is substantially different from their adoption in the developed world. This is generally due to the difference in the scale effects of both regions based on their respective capital resources. Two works on this issue are Bell (1972) and Stewart (1972). The thrust of the former focuses on the scale effects of 'Green Revolution' technologies on farm size. It is determined that in the context of northern Indian agriculture, these technologies are scale-neutral (where farm production capacity is concerned) and can consequently be applied without economies of scale, giving advantage to large farmers. However, this position has now been rebutted because it has been observed that green revolution technologies are primarily diffused to and retained by wealthy farmers (Lipton, 1989).

Another area addressed is diffusion. One of the ideas introduced is that in the context of an exceptionally large country, such as India, which has many more farmers than extension agents, the agents should focus on training 'progressive farmers' who are keener on training nearby farmers regardless of their production capacity. This is based on the assumption that the inputs used for production will be scale and size neutral, meaning that, regardless of the amount of land, each farmer will have yield increases from the technology proportional to the inputs and acreage farmed. Depending on the technologies analysed in the empirical study, scale could be a highly significant factor in adoption choice. However, since the prospective population of small farmers are relatively resource constrained, it is assumed that the introduced technologies will have minimal scale bias. What differentiates Bell's (1972) view from that of Stewart (1972) is that Stewart bases the applicability of the technology on the capital to labour ratio. Hence, if the country has a low capital to labour ratio, then capital intensive goods will not be used, because farmers would want labour intensive innovations, as there is an excess of labour and a shortage of capital. Furthermore, scale effects are directly affected by this ratio. For example, areas with high capital to labour ratios would adopt more productive technologies because they have the capital to make such investments. Depending on the empirical population, labour or capital could be a constraint. Technologies that increase or decrease the labour demand could be attractive, depending on the capital resources and unemployment levels.

2.1.3 Skill Level

Another key characteristic is the ability or skill level of the farmer. This is discussed in Kislev and Shchori-Bachrach (1973). The model devised is premised on the assumption that those who are highly skilled will adopt first and will be the first to cease use of the innovation. The idea is that those that are more skilled will be more eager to adopt a new technology because they have a superior level of ability in farming and will be more apt at learning new technologies. However, after the highly skilled farmers adopt, supply will increase and the price will decline, and in consequence the highly skilled farmers will stop using the innovation.[11] Hence, the well skilled farmers will be in a continuous cycle of adoption in order to maintain the exceptional returns that they receive from introducing more productive inputs.[12]

There are numerous ways in which social behaviour would be significant in the influence of skill on adoption. The three elements of social behaviour studied here are all directly related to farming ability. Social learning is the key, since ability is largely related to the ability to learn techniques from others. Social interactions and networks would be the determinants of the level of learning. One's frequency of opportunity to engage in learning based on the non-market characteristics of individuals within one's reference group, such as ethnic group, gender, schooling, or bar attendance, would be a substantial determinant. A person's interaction with their reference group could bond them to the respective norms and hence influence their learning behaviour. Networks would be important through strong social ties such as risk-sharing relationships. This could be within kinship networks where there is an intimate concern with one another. Thus, if a member learns of a new technique they would train others and it would subsequently be diffused to enhance the welfare of the entire network.

2.1.4 Market Density

One of the most important reasons for innovation adoption is market demand. Demand for the commodity is the dominant incentive for innovation investment. Particularly in the case of capital-constrained small farmers, market demand must be strong, because of the fragility of the household and community economy. A seminal work analysing the importance of market density is Griliches (1957), probably the most prominent paper in agricultural adoption. The primary finding of this work is that within the United States hybrid corn varieties were adopted based on market density, meaning that when there is a high concentration of demand within a farmer's locality, there is a much higher probability that the High Yielding Variety (HYV) seed will be adopted, and within less time than for farmers in less dense markets. This paper is significant here because it indicates a crucial variable in agricultural adoption.

[11] This is dependent on the commodity, the technology and the market
[12] As note 10.

2.1.5 Investment Delay

It is significant to understand the time between the introduction to and the adoption of an innovation. During this period a farmer updates their information to increase their confidence in making the decision. In the 1970s there was a small revolution in the modelling of agricultural adoption because of the introduction of the Bayesian methodology. Before this, information acquisition was measured as a one-shot process wherein a farmer collected information at one point in time and never revised their knowledge. Of course, this is a significant constraint on modelling the information acquisition process since farmers are constantly seeking more knowledge in order to decrease the uncertainty in the technology's application. Thus, the most realistic scenario is a model that accounts for this repeated updating of knowledge.

The seminal paper in Bayesian adoption modelling is Lindner, Fischer, and Pardey (1979). What is significant about this work is that the formulated model explains the variation of farmers in the delay of innovation assessment. It is shown that the difference of the expected costs for two innovations determines the one that the farmer will adopt. This is a common determinant of whether a farmer will adopt a technology. If it is calculated by the farmer that the innovation's expected costs are low for the scale of production, then the farmer will probably adopt. A break-even point or threshold of the expected cost is modelled for determining preference. A Bayesian model is given to estimate the posterior distribution for the expected value of the break-even point, which represents the probability of the expected mean cost of the innovation. Another aspect covered is the cost of information collecting. It is found that the cost of collecting information for an innovation increases with the number of users, but decreases over time. The reasoning is that the variance of the information increases with the number of users, thus the information's validity is more difficult to discern due to its variability. But as time passes there will be a convergence in the population towards the most viable information, thus the cost of collecting information will decrease.

In actuality the cost of collecting information could decrease when the number of users increases. It depends on the spatial distribution of the users, and the interactions and networks among those users. Moreover, it depends on the respect that those users have within the community. If the increase in users is concentrated in the group of the most capable and respected farmers and they are within an individual's reference group and social network, and are in close proximity, then the increase in users will actually decrease the individual's costs of acquiring information. It is likely, however, that this cost of collecting will decrease over time because as more users trial the innovation their knowledge will increase and consequently the expected marginal costs will decrease due to the lower information uncertainty. With respect to social effects, the expected costs could depend on the perception of the other farmers in an individual's network. For example, there could be leaders in the network that instigate herding of information, or the network could have characteristics that influence its perceived cost of a particular technology. Perception could also be affected by social interactions based on one's reference group characteristics. Thus, if a farmer's reference group expects high costs then the farmer will probably share that expectation.

2.1.6 Risk, Uncertainty and Observability

Risk and uncertainty are significant concerns in adoption. The interest underlying all the variables of adoption is their effect on the farmer's risk and uncertainty about the innovation. It is a principal issue of adoption. Particularly in terms of resource-constrained small farmers within unregulated markets, it is an absolute must that farmers have a complete understanding of the adoption risks. However, it is also substantially more difficult for these farmers to reduce risk and uncertainty because their environment is substantially more insecure. For example, the consistent provision of utilities is assumed in developed countries whereas in developing countries it is either nonexistent or sporadic (Winkler et al., 2011). Also, since farmers in developing countries are often uneducated about modern agricultural technologies there is a substantial uncertainty with respect to adopting sophisticated innovations (Herdt, 2012). Additionally, because many farmers do not have substantial formal education it is difficult for them to seek information concerning the innovation, since such information is cloaked in formal and jargon-based western expositions. Hence, providing the means to reduce risk and uncertainty of innovations is central to increasing the probability of adoption for small farmers. Therefore, properly estimating the influence of risk and uncertainty on adoption is critical. It is an exceptionally difficult variable to identify because it can be correlated to almost any other variable.

For understanding this issue Marra, Pannell and Ghadim (2003) provide a clear review and conceptual analysis. Their paper begins by reviewing the history of the literature. What is important about this work is that it reviews the empirical literature on measuring risk and uncertainty. The idea conceptually overarching the paper is that the aim of analysing risk and uncertainty is to understand how to spur farmers from a state of awareness of an innovation, towards adoption. This precisely encapsulates the purpose of risk analysis and gives the proper direction for effective study. The primary focus in this work is to understand how learning reduces uncertainty and consequently risk in adoption, particularly through improvement of skills and informed decision-making. As opposed to other works, the analysis is within a financial framework. There is significant discussion about the irreversibility of investment, sunk costs, NPV, option value, etc. Due to the limited capital resources, the small farmer has to be extraordinarily careful in making substantial capital investments. Small farmers have to spend more time learning in order to develop their skills and knowledge to drastically reduce the risk and uncertainty in adoption. Another point made is that small farmers in variable agro-climatic areas cannot rely on learning from surrounding farmers; it is substantially more difficult for them to reduce their uncertainty because the responses of crops on their land could be completely different from those of their neighbour, due to plot size and agronomic variation. Such circumstances make trialling necessary to determine the productivity of the crop. Based on this analysis, observability is diminished as a potential method for reducing uncertainty.

Observability can be viewed as a risk reduction mechanism. This phenomenon is akin to the neighbourhood effect. The primary distinction between the two is that observability is based on the observation of only one farmer, holding space constant, by another farmer or group of farmers, whereas the neighbourhood effect is based on the effect of the aggregation of adopters on other farmers. Thus, space and density are absent from the

effect of observability. It gives a simpler look at the effect of the responses of known farmers to adoption. Observability could be seen as part of the neighbourhood effect. Distinguishing these two effects is significant, however, because it gives more flexibility and precision to the model. For example, estimating for the neighbourhood effect could actually be capturing observability, which would mean that the model would be misspecified. In turn, using observability as the correct variable would completely change the representation of how farmers are learning to adopt an innovation and would make the estimation more precise.

Dimara and Skuras (2003) take an innovative approach to modelling adoption observability by applying an established econometric technique. The use of single stage analysis is normal throughout the adoption literature, but this paper takes a two stage approach, which the authors call the 'partial observability process'. A single stage approach assumes that the producers are fully aware of the new technology, but the two stage approach uses a model wherein the producer can be aware and not adopt in the first stage due to an externality, and then adopt in the second stage when the externality is quelled. It is also noted that this could be extended into a three stage approach where in the first stage the producer is unaware of the innovation, in the second stage the producer evaluates the received information, and finally in the third stage the adoption decision is made. The multi-stage approach recognizes the asymmetry of information and the learning process that is inherent within a population of producers. This is directly relevant to all farmers because they persistently seek new information to reduce the uncertainty in adoption. The results from using this new method indicate that there are more adopters than estimated under the single stage approach.

2.1.7 Innovation Perception

In some cases the most important adoption variable might be the most subjective. A particularly interesting variable is perception. Perception represents the perceived value of an innovation's attributes. Adesina and Zinnah (1993) argue that this should indeed be its own conceptual framework for adoption analysis. They note that there are two established paradigms in studying adoption: innovation-diffusion and economic constraint. However, they state that a third should be established premised on the adopters' perception because of the significance of perception to adoption. Their argument is supported by the estimation of the perception of rice using binary variables of a number of perceived characteristics of the crop. The perception variables are all found to be significant. This study is closely related to this research because it estimates the perception of a population of poor small farmers. It indicates that the perception of farmers is an important adoption influence. A particularly significant variable is the taste of rice. It is shown that the local varieties of rice would have a superior taste to the modern variety.

Another paper estimating the affects of farmers' perceptions of agricultural innovations on adoption is Adesina and Baidu-Forson (1995). Empirical analyses are performed on data from Burkina Faso and Guinea. Two regressions are estimated for perception. One regression uses the dependent variable of the share of sorghum cultivated and the other uses the share of rice cultivated. From the results it is shown for both countries that the

cooking perception of the innovation (sorghum and rice) significantly increases the amount cultivated. This study reinforces the previous paper in two ways. First, it reiterates the results of perception significance. Second, the perception of culinary attributes is the most significant variable among those given for perception. The perceived quality of the crop for food preparation and consumption are strongly significant to its adoption.

2.1.8 Packaged Innovations

One of the most common forms of innovation introduction is through packages. This developed through the revolution in seed technologies that required specialized support inputs. Throughout the 1970s, after the development of rice, wheat and maize HYV, there was widespread promotion of these technologies by the extension agencies of developing countries (Goldman and Smith, 1995). The primary inputs accompanying these seeds were pesticide and fertilizer. Such an initiative gave the farmers more choice about how to apply the innovation. Although the purpose of these packages was to increase national production, many farmers made input combinations based on increasing profits, not yields. The variables determining the profit of the farmers must be well understood to know how the inputs will be applied to maximize profits.

Byerlee and Hesse de Polanco (1986) study the impact of differing rainfall zones on the multi-stage adoption of technological package components. What is significant about this work is that it concentrates on agro-climatic characteristics. Since small farmers are more prone to variation in environmental and agronomic variables, it is a crucial aspect of study. It is shown that the impetus for adoption of any of the components is profitability and not increased yields. Moreover, the main determinant of adoption is rainfall. For the wet zones the components were adopted quickly because of the perceived increased profit with favourable rainfall conditions. Also, they were adopted sequentially based on their profitability. There was a substantial lag in adopting any components for the dry zone due to the higher risks from unstable rainfall; however, the rate of adoption was higher because of the market price advantage. It is apparent from the given data that there is sequencing in adoption for these farmers, and that the reason for this is ensuring risk reduction and profitability. At the time of publication, this work countered the literature's theme of package adoption that was primarily concerned with single stage adoption and assumed that full adoption maximized utility. This paper brought forth a new and real-world understanding of packaged adoptions focused on profit maximization and strategic input adoption.

In contrast to the single equation model predominant in the literature, Smale and Heisey (1993) apply simultaneous equation estimation for the modelling of the concurrent adoption of technologies. The reason for this is that the innovations are adopted jointly, thus they are directly related to one another. Another methodological innovation is the use of the Tobit model in structural equations. Instead of using a discrete dependent variable, the authors use censored variables that represent the highest proportion of land to which the innovation was applied. This is done to account for the extent of adoption, rather than simply adoption. The data that is estimated is of seed-fertilizer adoption for Malawian farmers. The simultaneous equation model presents more significant coefficients than the

single equation model. The main finding of the estimation is that consumption pattern determines if HYV seed is adopted. For example, those who consume the local varieties of maize are more interested in the quality of the maize than in high yields, and would not be as inclined to adopt HYV seeds as the traders, who want to sell as much as possible. Also, HYV maize and fertilizer are determined to be adopted jointly. Methodologically, this paper introduced two substantial contributions to the literature through the estimation of simultaneously adopted innovations.

2.1.9 R & D and Diffusion Systems

At the centre of the innovation process is the research and development system. Before the sweeping structural adjustment programs of the 1980s, most developing countries had formal, state-based, hierarchical agricultural research and technology diffusion structures. Biggs (1990) contrasts this system with a more appropriate approach for small farmers. The centrepiece of the prior research and development system was the national agricultural research centre. Essentially, innovations were developed at the institutes, in conjunction with international agricultural research centres, or were simply adapted from the international research community and then disseminated to the farmers. What is historically important about these research systems is that they were technocratic. Although there were exceptions, they were steeped in formally structured systems of agricultural development and extension. Such structure of technology development and promotion stemmed the ability to develop applicable technologies for small farmers in more complex farming systems as compared to large landowners. Although there was an exceptional increase in yields, it was concentrated among large landowners or state farms because they had the size, scale, and resources to apply the new innovations. This is known as the central source model.

This is a system of agricultural development and dissemination based on a strictly hierarchical system. The diffusion process within this system is rigid and linear. Each type of farmer is theoretically determined to be suitable for a particular type of technology based on economic status. This demarcation of farmers for innovations lacks socio-economic, agro-climatic, infrastructure, social and household economic characteristics. It is simply detached from indigenous forms of farming and linked strictly to scale and size with respect to productivity. The system is strongly biased towards the development and maintenance of large farms as opposed to the complex livelihoods of small farms. A further display of the disregard for the needs of small farmers is that farmers' skill and information is not integrated into the research and development process – meaning that the knowledge and experience necessary to successfully develop technologies for the smallholder is not taken into consideration. The contrast to this model is the multiple source model, based on multiple sources collaborating in innovation development. A system under this model is non-hierarchical and integrates the farmers' needs into research and development. For the small farmers' benefit this is the ideal type of model to use to develop a system of research and development. This is because the system accounts for the special welfare-increasing needs of the small farmer. The differentiation between the central and multiple source model indicate that the type of agricultural research and

extension system developed is crucial to the adoption process. If innovations are developed that are unsuitable to the needs of the farmer, then the probability of adoption is minimal.

Another analysis of agricultural adoption research initiatives is the excellent Merrill Sands (1986) critique. The primary criticism of research and technology promotion is that they often lack that rigorous study of socio-economic characteristics which is vital to effective adoption. It is stated throughout that many agricultural development research efforts concentrate on maximizing yields rather than creating a technology that will fit within the household economy of most farmers. One of the key issues in small-farm development (as the title states) is closing the gap between the researchers and the farmers, in order to create a collaborative environment wherein both parties are active in developing a technology that suits the socio-economic needs of the farmers. This is a superb work, which displays as many as possible of the issues that prevent proper small farmer adoption. Although the work is dated, its critiques are still relevant.

A final work is Biggs and Clay (1981) which provides an analysis of the role of farmers in the agricultural research and development process. The other role of this paper is to provide a clearer understanding of the role of research systems, as well as how those systems should develop within the biological, ecological, agronomic and socio-economic environment of the respective crops of interest. The paper indicates different ways of perceiving research and development that are tailored for small farmers. The prevailing theme is that small farmers in developing countries, due to their limited and sensitive resources, need to be better supported and provided with more resources to implement innovation.

2.1.10 Education

A large literature has developed on the effect of education on agricultural adoption (Feder, Just and Zilberman, 1985; Appleton and Balihuta, 1998). The underlying logic is that farmers who are more able and confident in acquiring knowledge are more capable in reducing the uncertainty in applying the innovation because they are reducing the information asymmetry in technology knowledge acquisition. An additional note is that more educated farmers will probably have a stronger relationship with the research and extension system, since they may well seek out information more frequently. Due to this, extension officers would probably favour them. Moreover, since it is easier for educated farmers and extension agents to communicate with each other, the extension agents will naturally spend more time with them since the teaching barriers are significantly less. What occurs in such a situation is that the productivity of educated farmers will consistently improve over that of those who are uneducated, *ceteris paribus*.

To further illustrate this Strauss (1991) estimates the influence of education on different aspects of the adoption process of soybeans and upland rice in Brazil. An important distinction made is the difference between education and experience. Experience involves knowledge that has developed over time from practice, whereas education is the ability to process information. Education is found to be significant in the adoption process, as

opposed to experience. It was particularly significant in soil analysis for adoption, which is possibly due to it being a more intellectually taxing activity. This supports the significance of education to the adoption process. An understanding of how education is effective in the adoption process is central, because it allows for the extension agent to tailor the training of farmers to their analytical strengths.

Weir and Knight (2004) estimate the affect of schooling on fertilizer adoption in Ethiopia. The main hypotheses are that educated farmers innovate with better farming practices, and are quicker to copy innovations, while those who are uneducated mimic those that are educated. A probit model is used for estimation wherein fixed effects control for village locations. Another interest in the analysis is of social networks. It is found that those with a higher education tend to associate with better informed farmers and consequently have a higher rate of adoption. An additional finding is that education within the village rather than within the household has a significantly stronger effect on adoption. Also, there is an indication of an education threshold, as the estimates for those that are educated past grade six do not show a substantial increase in the adoption rate. This work reinforces the beneficial role of education in adoption.

2.1.11 Credit

A common barrier to adoption is credit (Feder, Just and Zilberman, 1985). Unless the technologies are subsidized to an affordable level, farmers must obtain credit to acquire the innovation. The procurement of credit can be an exceptionally complicated process for small farmers (Feder, Just and Zilberman, 1985). The principal impediment to securing a loan is the possession of acceptable collateral. For small farmers in developing countries, their tenure agreement or the size of their land often does not suffice as collateral for financial institutions. This could be due to tenure agreements being informal (Feder, Just and Zilberman, 1985). Moreover, there are other practical impediments such as the time and financial opportunity cost of obtaining a loan. In rural areas bank branches are sparse, thus the time and money spent in travelling to a branch can be substantial, particularly if the service in those branches is irregular. Because of this, farmers are dissuaded from pursuing credit. Additionally, the interest rates for small farmers may be exorbitant because of the high credit risk label they are given, since they do not have formal and regular employment. Moreover, the timing of the loan may be unsuitable for the needs of the farmer. If the farmer needs the loan for a particular period of time, but the bank is not reliable in releasing the funds, then the cost of obtaining the loan increases even more.

A paper that illustrates the affect of credit on adoption is Moser and Barrett (2003). The focus of the study is on the adoption of the System of Rice Intensification (SRI) in Madagascar. A main problem with the adoption of the SRI is that the period in which fields need to be prepared is the time when farmers are working to eliminate their cash constraint. This means that farmers are employed as day labourers to generate enough cash for immediate consumption. Due to this critical need, farmers cannot allocate the time or hire labour to prepare fields for SRI. In order to correct for this problem, credit would be needed to hire labour to implement it. However, credit rationing and the consequent exceptional interest rates driven by extraordinary demand prevent farmers from obtaining

credit. This makes adoption of SRI impossible for small farmers who do not have the resources to finance hired labour. What is important to note about this situation is that the credit constraint is with respect to an adoption input. This is something that must be taken into account, because a person might misconstrue a credit constraint as being directly related to the adoption of the technology, when in fact it relates to a factor complement.

A more common influence of credit is found in Feleke and Zegeye (2006). This is a study of the adoption of maize in Ethiopia. Here it is shown that credit access increases the probability of adoption by four times. This indicates that credit is essential to the adoption of maize. The reason for such a strong significance is that the region in which the study was conducted has a strong food deficit because of poor production. In this case, poor farmers would be more inclined to adopt to raise their level of production. Additionally, since this is an exceptionally poor region, credit would be needed, as they have a liquidity constraint.

To provide a contrast with the literature, Bekele and Drake (2006) find credit insignificant in the adoption of soil conservation technologies. There are a few reasons why this might be so. The results indicate either that there is not a credit constraint, that credit markets are not functioning or, most probably, that the factors are unimportant to soil conservation. The two credit variables estimated are fertilizer and food credit. A reason why fertilizer credit is not significant is because the area of Ethiopia studied has some of the worst soil degradation in the country. In such a situation, small farmers are going to be more apprehensive about a soil conservation project as it may take several years for the soil to rebuild its integrity. Even if they do implement it initially, it will probably be poorly maintained and removed altogether because substantial land is used to construct the barriers. Since these farmers are very poor it is unrealistic for them to wait such a long time to reap the benefits of the investment. For these reasons, fertilizer credit would be insignificant to the adoption of soil conservation. Another form of credit based on food would be more applicable, by reducing off-farm household labour. Since the construction of soil barriers is labour-intensive, household members would not be able to work on other farms to secure immediate cash needs. In this situation, households would seek food credit to enable household members to work on soil conservation. However, if soil conservation is not highly significant to the population then strong measures would not be taken to ensure the implementation of the soil conservation project. This study broadens the view of the effect of credit on adoption by showing how resistance to adoption can make its influence insignificant

2.1.12 Tenure

The significance of tenure to adoption relates to the NPV of the productivity of the land. If tenure is uncertain then the NPV of the land is uncertain and investment will be negligible if not nonexistent. If the tenure is certain then the NPV is high and long-term investment will be made. The general principle is that having secure tenure determines whether or not a farmer will invest in their land (Feder, Just and Zilberman, 1985). Since tenure can vary by country, municipality, and community each particular tenancy situation can be different. However, there are a few common types of tenure: sharecropping, rental,

freehold, and communal (de Janvry et al., 2001). A sharecropper is unlikely to invest in the land. One reason is that the quality of the land is probably poor. If a farmer decides to allocate a piece of land for sharecropping it is going to be marginal land, because they would retain the best crop-land for their own cultivation. In addition, sharecroppers tend to be the poorer farmers (unless they are sharecropping in order to access a specific factor from the landlord) since they do not have the cash to rent land. This means they would have minimal cash reserves, which bars them from making any investment. For renters, investment is more probable as the farmer would prospectively have a longer time horizon because he has to expend more resources to obtain the land. This might be the case in an area with poor credit markets. If a farmer is not able to obtain sufficient credit to purchase a piece of property, he will be forced to rent. Thus, he would be a long-term renter and it would be in his interest to invest in the land, since he will reap the benefits in the future. If a farmer is a freeholder of land then it is assumed that tenure would be positively related to adoption since the land would be privately owned. However, as with all tenure types, this situation also depends on the respect that is maintained for tenure agreements. Lastly, investment in communal land is possible, but is completely dependent on its organization.

The paper by Place and Otsuka (2002) provides an example of the influence of tenure on adoption. .It analyses the affect of tenure in Uganda on the adoption of coffee and fruit trees. Three types of tenure agreements are analysed: mailo, public, and customary. Mailo represents privately held land controlled by ethnic groups, public land is state-owned, and customary land is owned by ethnic authorities and allocated based on need. It is found that long-term investment in coffee does not differ significantly among the tenure systems. The reason is that coffee enhances land-rights since it is a lucrative perennial cash crop. Hence, the planting of coffee is negatively related to the uncertainty of tenancy (tenure is endogenous to tree planting). An estimation was also performed on the influence of tenure systems on planting fruit trees. It was also found to be insignificant. One interesting finding is that tree planting density is positively related to the length of time that the parcel has been held by the current landholder. This could indicate that the length of occupancy increases the security of tenure rights and consequently increases the probability of investment. A result that could indicate future investment is that mailo and public land owners have a higher probability of fallowing. This shows that they have long-term concerns for land quality and would assumingly be more inclined to make investments. Due to customary land having more uncertain tenancy, since individual land rights are not given to farmers, occupants would not be willing to fallow land in order to improve soil integrity. Although the estimations indicate that tenancy is not significant in determining tree planting, the fallowing of land might indicate that tenure is significant in aiding future long term investment.

The work of Kabubo-Mariara (2007) provides an additional example for the importance of tenure through soil conservation adoption. Using data from Kenya, it is found that having more secure tenure increases adoption. This is based on the long-term investment argument. If land tenure is secure then farmers will seek methods to improve their land in order to increase its NPV. For this study two sets of land tenure are estimated with respect to adoption: private, and group ranches. A group ranch is a collection of farmers of varied tenure agreements under the auspice of a single landlord. Private tenure is shown to have a significant positive relationship with soil conservation. Group ranches are also shown to

be significant and positively correlated to soil conservation, but almost exclusively with respect to the most secure type of tenure in the system. These findings reinforce the significance of tenure security to investment by small farmers.

2.2 Social Behaviour and Agricultural Adoption

As with agricultural adoption, the social behaviour literature is immense. The area began in sociology and psychology but now has spread to and flourished in economics. Principally, the study of social behaviour regards any study involving social influence. The most common definition for social behaviour, which will be applied here, is the study of the effect of non-market social influences on economic behaviour (Manski, 2000). What is so intriguing and exciting about this area of research is the objective of creating an interaction theory intertwining sociological and economic methodologies. As noted in Durlauf (2001), this is one of the most promising areas of (social science) research. The intention for this half of the literature review is to provide a conceptual understanding of social effects, particularly in terms of adoption. Two sections are given: the first reviews agricultural social behaviour literature; and the second analyses the non-agricultural and more theoretical social behaviour works.

Agricultural

The purpose of this section of the review is to give an understanding of the empirical position of social effects in agricultural adoption, particularly within developing countries. Moreover, the issues regarding the identification (conceptually not econometrically) and the empirical analysis of social effects are highlighted. Also, three aspects of social behaviour will be reviewed separately: learning; interactions; and networks. The intention of this is to properly define the characteristics of each within their own domain in order to differentiate social behaviour.

2.2.1 Social Learning

Particularly since the work of Besley and Case (1993), there has been a substantial development in social learning agricultural adoption papers. Excluding Yamauchi's learning and human capital paper, the papers that are presented here are the most pertinent with respect to developing country agricultural adoption.

As defined in the introduction, social learning regards the dissemination of information through social effects. The seminal paper in modelling this effect is Besley and Case (1993). Although this paper was given in the previous section as a learning-by-doing work, it also made a significant contribution to the development of the agricultural social learning literature. Through learning externalities, it is indicated that learning is based on observing the yields of other farmers or being taught by early adopters, which is translated as expected gains in the model. No concessions are made for the learning process except

for it being in a Bayesian updating format. This paper gave a platform for future social learning works.

Following the work of Besley and Case (1993), Foster and Rosenzweig (1995) analyses learning by doing and learning from others in agricultural adoption. Indian Green Revolution data is estimated using a target-input model. This modelling approach is based on estimating the optimal input use of a new technology that has an unknown productivity. An additional note on this model is that the profit of the technology increases over time as one's experience with the technology increases. It is found from the estimation that farmers with more experienced neighbours are significantly more profitable than those with inexperienced neighbours. Moreover, more of the former farmers will probably devote more of their land to the new technology. Another aspect that supports the argument for social learning is that farmers tend to delay adoption if their neighbours have adopted, in order to reduce their uncertainty through learning. Thus the experience of farmers' neighbours is significant in determining adoption. This is supported even more by the display of poor farmers with rich neighbours having a faster rate of land allocation for HYV seed than poor farmers with poor neighbours. What this indicates is that poor neighbours wait to learn from the well endowed who are the first to adopt, and when it is shown that the technology is profitable then they are able to adopt quickly. However, in the case of poor farmers with poor neighbours the uncertainty is higher since the adoption of the innovation is staggered due to resource constraints, which is why the adoption rate is slower. Both of these situations are assumed since adoption is strongly determined by wealth. What is particularly important about this paper is that it provides a strong analysis of the link between experience and wealth in the social learning process.

To understand the prospective speed and extent of social learning within a population, the barriers impeding information transfer must be analysed. Understanding the heterogeneity of the population is significant to the learning process because it is representative of the amount of noise.[13] Heterogeneity and homogeneity can be applied to innovation adoption analysis in several ways, but the foremost concern is the noise that is endured during the diffusion process. For example, if a population of farmers is highly heterogeneous in regards to the characteristics of the people, then there could be less learning because there are social barriers preventing them from interacting. However, it could also be the situation that heterogeneity fuels the learning process. It is found in Yamauchi (2007) that highly knowledgeable farmers assist those that are substantially less capable. Here, it depends on how noise is defined in regards to estimating its population variation effect on learning. The works of Munshi (2004) and Yamauchi (2007), each give an interesting analysis of this issue in learning and innovation adoption. The two papers are empirical estimations that use the same Indian Green Revolution dataset. Munshi analyses heterogeneity in agro-climatic characteristics of two different crops and the effect on learning and technology diffusion. This differs from Yamauchi, who estimates social heterogeneity in schooling in Green-Revolution communities.

[13] Noise represents the variation in the social characteristic

One of the many issues in adoption is why innovations that have high returns for an individual are not adopted by their neighbours. The issue concerns the variation in the characteristics of the farmers and the suitability of innovations for each individual.

Munshi (2004) investigates this through the difference in social learning about HYV wheat and rice in their respective predominant cropping areas in India. The central concern is heterogeneous populations, and is represented by rice since it is more spatially variant with regards to agro-climatic characteristics. It is assumed that the agro-climatic heterogeneity would impede the social diffusion of information, since different locations necessitate different information. This situation counters that of wheat in India, where there is little agro-climatic spatial variation (according to the authors), which enables a consistent flow of social information. Notably, the hypothesis of the paper is supported, illustrating that social learning amongst rice farmers was less than that amongst wheat farmers. Since information was less transferable in the rice regions the adoption rate was lower. This is because farmers had a lower level of information regarding the new variety of rice as compared with wheat. One interesting finding of this circumstance is that those in heterogeneous populations will be more inclined to focus on individual rather than social learning. This means that trialling and experimentation is more prevalent among these populations because it reduces the uncertainty with respect to the innovation. Moreover, this displays the importance of information to the learning process, since those who are unable to obtain information from others seek to develop it independently through their own experimentation.

Although the next work does not regard social learning for innovations, it studies the influence of social learning among rural households. What is important about this paper is its analysis on how the inequality of a factor in a population influences its acquisition. One particular way that this type of analysis could be significant to agricultural adoption is with learning new planting techniques. Those that have a sophisticated knowledge of planting will have higher returns because their cropping is more precise in producing higher yields. If there is remarkable variation in planting knowledge within the population, then the rate at which the returns of the population's members converge should be high, *ceteris paribus.* Moreover, the rate of convergence should increase monotonically with inequality. Meaning, efficiency is higher with more inequality. Yamauchi (2007) investigates how heterogeneity in Green-Revolution Indian communities affects schooling returns. The hypothesis is that social learning is most efficient when inequality in schooling is greatest. This means that if there is a greater variation in the level of schooling then those with a lower level of schooling will learn more about the returns of those neighbours with high learning levels.

Furthermore, the greater the concentration of those at the extremes of the schooling distribution, the higher the marginal returns from schooling, because the proportional return increases monotonically as the level of schooling decreases. Another hypothesis is that the speed of learning will be high in the initial periods but decrease over time. This reflects the efficiency of the learning process. As stated before, higher inequality induces a faster rate of convergence, and this is particularly true in the beginning stages since inequality is at its highest point. The results indicate that both the hypotheses are true. Also, the proportion of educated households significantly increases the effect of village-

specific schooling returns on the enrolment rate. As an example for adoption, if there is a higher proportion of sophisticated planters, then the increased returns to sophisticated planting will increase the adoption of those techniques due to the attractive returns. Another interesting finding is that there is a unique optimal schooling distribution in each village of the parents' generation for maximizing learning. Meaning, each village has a particular proportion of educated households that is most capable of facilitating learning.

2.2.2 Social Interactions

Minimal research has been undertaken on the influence of social interactions on agricultural adoption. The intention of this section is to give an empirical introduction to the significance of reference group interactions in farmer adoption.

Social interactions concern the effect of group characteristics on production and learning. This is important for this study because within the farming communities there are potentially informal groups, such as rotating credit or parent teacher association members, with certain endowments or intrinsic behaviours that tend to associate with members who produce due to learning. Moreover, this could make these people more inclined to adopt innovations. Van den Broeck and Dercon (2011) provides work on this situation using primary data. What is most important about this study is that reference groups are empirically identified. This enabled it to correct fundamental identification issues, as the data was collected in this fashion. The paper indicates that some groups learn faster than others because their characteristics give them particular advantages. An additional interest of the work was the influence of network links on information diffusion.

Van den Broeck and Dercon (2011) provide a solid empirical analysis of the effect of social interaction on agricultural adoption in Tanzania. The most appealing aspect of this paper is that, instead of theoretical analysis, it focuses on empirical issues associated with estimating social interaction effects. What sets this paper apart is that it is one of the handful of papers that uses primary data. Due to this, it is able to solve some of the network identification issues caused by data limitations. This is critical because if the data and the model do not properly identify the relationship between the group and the individual then the estimation results will be spurious. One issue that the primary data solves is that of omitted variable bias. This is solved by including exogenous characteristics not normally captured by secondary data sources. The data availability reduces the possibility of the coefficients being biased since variables that would have otherwise been left out are captured. The technique used to account for social interactions is social grouping, wherein three social groups are identified as conduits for social interaction, and are the determinants of social effects for learning. The farmers of the groups that have higher coefficients with respect to adoption will have stronger endogenous social effects with regards to adoption. The results show that kinship groups have the strongest endogenous social effects and that farmer groups with farmers viewed as agricultural advisors reduce these effects.

2.2.3 Social Networks

Recently, there has been substantial growth in the literature on agricultural adoption and social networks. The papers described here signify the most significant empirical works on agricultural adoption. The objective of this section is to exemplify the empirical issues confronting adoption and networks. An additional focus is the formation of rural networks as shown by Fafchamps and Gubert (2007). The first two papers concern observability and risk-sharing whereas the final two focus on adoption.

The influential empirical paper of Conley and Udry (2001) models learning through networks based on observability. This means, for example, that farmers who can observe talented farmers are more likely to adopt than those who cannot, because they can also observe the farmers' gains from adoption.

Conley and Udry develop an empirical model of social learning through networks on fertilizer adopters in Ghana using the observation of the expected value as the adoption criterion. The two primary assumptions of this model are that each farmer holds information on the experiments of all other farmers in the village, and that they observe other farmers with no loss of information. Another interesting assumption is that the farmers are acting simultaneously in fertilizer adoption, which means that the adoption of other farmers can only be observed in the subsequent period. One of the important points that they make in regards to having imperfect information is that farmers will seek to understand how their neighbours learn in order to increase their own level of information. This follows the standard thinking on learning and risk reduction. If farmer A teaches farmer B a new technique, but the transaction costs are too high for farmer A to teach farmer C, then farmer C will try to learn how farmer B learned in order to eliminate his information asymmetry.

The amount of risk accompanying the innovation adoption is central to the adoption decision. One of the ways that actors reduce this risk is by forming welfare sharing or insurance networks. By doing this, actors are able to decrease their risk and potentially adopt innovations that could substantially increase their welfare. These risk sharing networks could be based on myriad of characteristics. Because of this it is important to understand what causes these network links to develop and persist. One of the works that estimates this relationship is Fafchamps and Gubert (2007). The purpose of this other paper is to understand the common attributes of members of insurance networks in the rural Philippines using social, labour, wealth and geographic variables.

Fafchamps and Gubert contribute to the developing literature on risk sharing in social structures and the estimation of dyadic relationships. Using data on rural people in the Phillipines regarding informal loans and gifts, the authors estimate the influence of socio-economic characteristics on insurance links. The dyadic regression estimates the directional effects in order to specify the models, which are variables of the differences and sums of the characteristics of the linked individuals, respectively. One issue that is resolved in the estimation is measurement error. Since the dyadic relationships are not independent, the error term is not going to have an expected value of zero. Another issue regarding the estimation process was a misspecification within the data. Network links are represented by the four individuals that each household would depend on in a time of

need. However, this is not specific enough because the household's network could be larger than this, and it could be biased towards those that are geographically near rather than those that truly have the resources to assist. The results indicate that age and wealth are the primary causes for having risk-sharing networks. The young often have links with the old for pooling health risks, and it is determined that most of those who have the resources to share will engage in risk-sharing networks. This important addition to the development network literature is due to the data, and the estimation methods for the correction of identification, specification and error correlation issues.

The purpose of analysing social networks is to understand how the structure of a society affects the diffusion of a choice. To represent this effect, the concept of strength of ties is reviewed. Strength of ties refers to the impact or influence of network links. For example, a farmer could be a member of multiple networks, but there are some networks that have a more significant influence on the behaviour of that farmer than others. To demonstrate this, we refer to Bandiera and Rasul (2006). This paper is directly relevant because it is based on the diffusion of an agricultural innovation through networks of resource poor farmers. Moreover, the econometric estimation is careful and thorough.

Bandiera and Rasul give a thorough analysis of the affect that social networks have on sunflower cultivation adoption in Mozambique. The primary importance of this model is measuring the propensity to adopt based on the social network size of adopters. As a reference group, family and friends are used as those that vary with the behaviour of the adopters' social network. In order to estimate the strength of ties of family and friends, religious social network groups are used as a comparative example for estimating the propensity of adoption based on one's social network. It is found that the strength of ties is important to adoption because the propensity to adopt within family and friends networks is four times greater than within religious social networks. The estimation process for the model is exceptionally robust in that it corrects for many econometric issues such as fixed effects for village specific influences, relevant proxies for risk and social networks, and correcting bias from informed and uninformed adopters. One interesting issue suggested for future analysis was that of reverse causality, wherein farmers befriend other adopters after adopting themselves, which could possibly bring forth an inconsistent estimation. This is because the link is being formed *ex post* due to adoption rather than the link acting as a pathway for adoption.

All of the previous empirical papers have focused on non-spatial characteristics of networks. These issues have included the number of actors, the number of links, etc. However, spatial analysis of social networks is probably the most developed statistical estimation technique for social networks. Since spatial statistics has considerable depth, it is most capable of estimating the intricacies of social network effects spatially. It must be understood that the obvious failing of the spatial estimation of social networks is that it centres entirely on the influence of space on behaviour. Hence there are non-spatial characteristics of social networks that are not captured. Another issue is that the observations being estimated must be immobile. Otherwise, the results have little validity because of stochastic change in their location. Even though there are issues with spatial statistics and social networks, its application could be valid in the area of innovation adoption among small farmers. Since farmers are usually immobile, the spatial analysis of

farmers' social networks could be suitable. However, depending on the plots' spatial variation, spatial analysis may not be appropriate in areas where farmers produce on multiple non-contiguous plots. Nyblom et al. (2003) also concentrate on agricultural innovation diffusion and make a substantial contribution to the empirical social network literature. Their paper is a thorough spatio-temporal analysis of diffusion that refines some established estimation techniques. In addition, multiple regressions are estimated using several spatial treatment variables to ensure that the spatial relationship that is being estimated is not capturing other spatial relationships among the farmers.

Nyblom et al. present a clear exposition of the identification of network connections and the spatio-temporal estimation of the adoption process for organic farming. This is probably the most rigorous development of spatial social network estimation. What makes this work exceptional is the amount of detail established in modelling the identification of interactions. For example, measures are taken to ensure that the order in which actors are interacting is indeed true. However, it must also be stated that in general empirical terms it is unrealistic to estimate the significance of network connections precisely, because relationships change and apparent relationships could even be intermediaries for the true relationship. Another aspect of identification is analysing how different variables affect adoption and how interactions of neighbours vary. This is denoted as confounding covariates, and causes bias that prevents the consistent estimation of spatial autocorrelation, as is used in this paper. As for the results, two of the main hypotheses turned out to be true. The first is that organic farming is associated with the size of the neighbourhood. The second is that new adopters cluster together. However, it is also suspected that spatial significance is due to omitted variable bias.

2.3 Non-agricultural

As opposed to the previous section, the concentration here is on social interactions theory. Other relevant topics included are identity, position, efficiency, and social learning and experimentation. Principally, the section illustrates the complexity of social behaviour analysis.

2.3.1 Social Interactions

Social interactions concern the study of the influence of reference group membership on behaviour. Within recent years there has been a rapid development in the field, particularly within economics literature. The seminal paper for this area is Becker (1974). Although this was published more than thirty years ago, it is fundamental to understanding the influence of social interactions on economic behaviour and is an important work in this field, since recent developments are exceptionally mathematically rigorous. Without properly understanding some core concepts of social interactions one can become lost in the new elaborate models.

The social interactions concept of Becker is based on the idea that each person seeks to maximize their social income, which is the sum of the production value of the social environment (social entities that increase productivity) and money income. This indicates

that individuals will actively seek to enhance their social environment in order to increase their production value. In farming, this is represented by farmers seeking to enter social groups that have production (or welfare) increasing resources. Those groups of farmers that place higher value on their social environment will presumably be more innovative and eager to adopt since the value of their social environment to increasing production value is higher. This differs from the contemporary conceptualization of social interactions because it focuses on the utility derived from social entities instead of the influence of endogenous social effects on behavioural choice. Moreover, it lacks the organizational constraint. Also, it is shown that as the contribution of a person's social environment increases, a person's welfare is determined less by his own income and more by the social interaction characteristics of the individuals in his social environment.

To illustrate how social influences are integrated into economic action the concept of embeddedness is used. It is argued that there has been a misplaced analysis of the role of social behaviour in understanding economic action. Embeddedness is significant to adoption and social networks because it provides a concept for deriving the ways in which social structures are integrated into economic behaviour. The seminal paper Granovetter (1985) analyses this relationship. What is particularly important about this work is that it properly encapsulates how the structure of society influences economic behaviour through the maintenance of social order and relations. Moreover, how it affects the development of economic institutions.

Granovetter (1985) discusses the interaction between social structures and economic activity. The tool of analysis is that of 'Embeddedness'. This term refers to the extent to which social structures guide economic processes. Basically, the paper uses this tool of analysis to explain myriad economic activities. A substantial portion concentrates on the literature, particularly classics, that have 'under- and oversocialized' economics and gives a critical review of those works. The main feature of the paper is that it addresses the idea that non-market societies have a more substantial amount of embeddedness than modern market societies. The reason for this is that premarket communities do not have the formal institutional economic structures that protect traders from shirking and contractual malfeasance. Due to this, those communities establish informal methods to protect against risk and uncertainty amongst traders, which are a reflection of the extension of social structures into the economic sphere. This is related to adoption through social interactions and networks. If a person's reference group or network shares these rules of social contract then farmers would be more inclined to adopt because of the enhanced environment of social security. This is particularly the case in terms of risk sharing obligations. With respect to the literature this is a seminal paper and provides a thorough analysis of the interplay of social structure and markets.

In order to properly estimate the influence of social behaviour, the problem of identification must be resolved. This refers to the issue of determining the relationships of variables. This is a common issue throughout econometric estimation. The seminal paper Manski (1993) analyses this issue, denoted as the 'reflection problem'. Charles Manski wrote three prominent papers (Manski 1993a, 1993b and 2004) in the field of social effects identification. Manski (1993a) and Manski (2004) are reviewed here. Although the former generally addresses the issue of identification in social sciences, it is of particular

importance to social learning for identifying what types of social effects (endogenous,[14] exogenous,[15] or correlated[16]) directly affect the acquisition of information. The latter paper focuses on the dynamic process of learning in the case of censored information. The paper rightly notes this as the 'selection problem' wherein actors have to choose from a censored and uncertain choice set to make their learning decision. If the estimation is not properly identified, the model will not reflect the relationships that it contains. In turn this will give a false representation of the effect that social learning has on innovation adoption.

Manski (1993a) gives a detailed exposition of theoretical modelling, and econometric estimation procedures for social effects. The primary concern is distinguishing the behavioural relationship between the individual and their reference group, and this two way relationship is the influence of the reference group and the individual on each other and their respective influence on the dependent variable. Taking account of this is essential to carrying out any social effects estimation since the purpose is to determine how social relationships affect a given variable. Without a properly constructed relationship, the results will be invalid. Significant time was allocated to the design and collection of appropriate data as well as to modelling the social relationships. The data collection was the most crucial aspect in resolving these concerns since a thorough representation must be given of the composition of the reference groups. What is particularly difficult about this, as shown by the paper, is distinctively identifying whether the average group behaviour is causing individual behaviour or is merely a 'reflection' of individual behaviour. As mentioned before, this is termed as the 'reflection problem'. A potential way for correcting this is through the use of lags for the social variables. This removes the contemporaneous effect and reflects the influence of the individual behaviour without the effect of the mean group behaviour. Moreover, it is noted that it would capture social effects better because it is assumed that they are not contemporaneous. The issue with this is that it is terribly difficult to discern the time of the lag. As a result, it is assumed that such a method would be impractical because such temporal data would be almost impossible to collect since the influence of the social effects is stochastic.

Of the three areas of social behaviour that will be studied, social interactions is the most difficult to define. Historically, the social interactions literature has been based in the economics peer effects literature. Peer effects regards the influence of one's reference group on one's actions. There was a particularly significant development in the 1960s and 1970s regarding social inequalities such as through the work of Loury, Coleman and Becker. However, there have been few attempts at creating an all-encompassing framework for social interactions. Durlauf (2001) is a remarkable effort in this direction in that it not only creates a framework for social interactions, but it also considers intertwining the theory of sociology and economics.

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[14] This is where the propensity of an individual to behave in some way varies with the behaviour of the group. Manski (1993a)

[15] When the propensity of an individual to behave in some way varies with the exogenous characteristics of the group. Manski (1993a)

[16] Where individuals in the same group tend to behave similarly because they have similar individual characteristics or face similar institutional environments. Manski (1993a)

The objective of Durlauf (2001) is to synthesize the empirical and theoretical modelling of social effects into a single framework. Specifically, the goal is to provide some premature concepts for integrating the social interaction theory of sociology and economics. The paper carefully derives the model by first providing a verbal exposition reviewing the sociological and economic literature, and discussing the respective analytical issues. With respect to sociology, two primary concerns important to adoption in this context are inequality and socio-economic concentration. Inequality could be a significant determinant of group formation. Presumably, those groups that have more resources will be more inclined to adopt because of their risk insurance. Consequently, those that do not have the resources will be less able to adopt. Socio-economic concentration regards the attraction of similar groups. When this occurs locations become more homogeneous. As shown by Yamauchi (2007), the level of learning is lower when schooling levels are homogeneous. Thus, as socio-economic groups concentrate and become isolated, the ability of the less skilled to acquire new information will decrease because of the absence of interaction with highly skilled farmers. Moreover, the assumed influence of the 'culture of innovation' among the highly skilled farmers will dwindle because of the group's removal.

For the economics literature, human capital is a primary area of analysis. As described by the previous literature of Kislev and Shchori-Bachrach (1973), Strauss (1991), and Weir and Knight (2004), human capital is a critical determinant of adoption. Education, experience and natural aptitude, which are the basis for skill development, determine whether a person will be competent at applying a technology. If one is not competent at the application of the technology then it will not be applied. Another interesting concern of Durlauf's (2001) paper is the inertia of the reference group behaviour of group members. This determines whether the influence of the behaviour of the group on the individual is strong enough to influence innovation adoption. Simply, it is the latency of the behavioural effect. An additional purpose of this work was to provide a more conceptual understanding of social interactions since it is implicitly stated that the area of social interactions in economic analysis is shallow, and that the complexity of properly modelling social interactions statistically is extraordinary.

Most of the social interaction empirical literature focuses on binary response situations such as pregnancy or smoking. The most prominent empirical and theoretical papers are based on the discrete choice model. This type of model directly applies to this study since adoption is a discrete choice. To analyse this, the Brock and Durlauf (2001) paper is reviewed. One of the innovations in this model is that of modelling the multiple equilibria of the social interactions behaviour choice. This occurs when there are multiple points of equilibrium due to utility complementing strategies between the members of a group and its mean behaviour.

Brock and Durlauf (2001) is one of the most significant papers within this literature. The focus of the model is on binary response situations such as engaging in legal or illegal markets. A key assumption of the model is that agents act noncooperatively, thus their decision choice is not based on a coordinated effort to maximize utility. An actor's utility is the sum of their private and social utility as well as a random error term. Social utility is the conditional probability that the actor places on the choices of all other agents. For the econometric model the main focus is resolving the issues of endogeneity and

identification. It is determined that simultaneous estimation and proper data collection are possible solutions. The latter is of particular interest.

As an overview, Manski (2000) gives a careful review of the development of social interactions throughout the social sciences, with an economic focus. What is beneficial about this work is that it properly synthesizes the many intricacies that plague the definition of this ambiguous field of study. It collects the most significant developments and discusses their importance; such a review is necessary whenever a new theory is progressing. Instead of introducing a new methodology Manski (2000) provides a reflection on the development of the economic analysis of social interactions. The paper consists solely of the development of the different analytical tools for social interactions and the new issues they have revealed. The first sections overview the themes from economics and sociology that have been used for social interactions and their respective strengths and weaknesses. Two types of interactions are suggested: expectations and preference. Expectations interactions regards those interactions that are based on observational learning. If a farmer primarily observes those in his reference group then this would be directly relevant to social interactions. Preference interactions occurs when the choice of agents depends on the preferred actions of others. Thus, the choice of adoption is dependent on the choice of adoption of others. The paper also revisits the main problems in the empirical analysis of social interactions, such as the reflection problem with regards to model identification and the use of subjective data. The main idea of the paper is simply to step back and look at the breadth of research linked to social interactions that has developed over the years and to synthesize the primary problems that hinder its proper analysis.

As an addition to the developing social interactions literature, Soetevent (2006) provides a comprehensive and clear analysis for correcting identification. The purpose of this paper is to survey all the recent empirical contributions for correcting the identification problem. Beginning with the Manski (1993) seminal work, the author outlines all the work up to the date of the paper. In addition to the survey, the identification solutions are deconstructed, synthesized and categorized within a framework of social interaction identification. Numerous techniques are described, but the paper concentrates on the use of instrumental variables, fixed effects, and structural equations. Also, the issues with data that plague estimation the most are shown to be simultaneity, correlated variables, and group endogeneity. In addition to the theoretical derivations, the final section of the paper reviews the application of identification tools within the literature. This gives a comparative analysis of how authors have been applying the techniques successfully in empirical analysis. A final note is the issue of determining who interacts with whom. The proposed solution for this is the use of random graph theory. This is one of the most important recent works since it clearly and strategically synthesizes the solutions for identification, which are at the centre of this research area.

Manski (2004) gives an analysis of identification in social learning. The problem of decision making within learning and social interactions is intricately modelled to show how agents make decisions under uncertainty of choice. For tractability, two main assumptions are made. First, for every feasible action, successive cohorts of decision makers have the same distribution of outcomes. Second, decision makers share the same

distribution of outcomes. The context of the decision choice for each agent is assumed to be constant in each period of choice. Another important assumption is that decision-makers seek to maximize their expected utility. Additionally, the underlying concept of the model is that, as social learning progresses, the uncertainty in making decisions tends to zero. To add to the complexity of the model a further point of analysis is the effect of countable or finite sets of decision on learning and the idea of a terminal information state wherein no further information can be acquired. Other aspects of the model involve the influence of actions that are dominated by all other actions in the choice set. It is assumed that these dominated actions will be eliminated because they do not further utility maximization. Moreover, a more ambiguous state is analysed where there are no dominated actions, hence agents must choose the optimizing actions among all those that further utility maximization. The final section of the paper gives an application of the model to learning innovations.

2.3.2 Identity

When analysing the interaction of social behaviours it is necessary to understand the social identity and position of agents in order to have a greater understanding of their behaviours. Identity is an enigmatic phenomenon because a single person can personify more than one identity and it can be difficult, if not impossible, to determine with certainty the identity of that person. This is particularly of concern in populations that have had substantial intermixing. Furthermore, identities of populations are often evolving because of changes within society. Ascertaining the effects of identity on social interactions necessitates an extremely intimate knowledge of the population.

Another determinant of social identification is position. This is also hard to specify since different communities hold different values for social position. Understanding the sensitivity of identity and position is important since societies differ in regards to the significance that they place on people having structural significance. Most importantly, these phenomena can be central to a person's behaviour. With regards to adoption, identity and position could be instrumental determinants since they represent social access keys. Holding a certain identity or position within a farming community could give farmers privileged resource access that enables adoption. Two papers led by Akerlof are presented here on these subjects. Akerlof and Kranton (2000) discusses the significance of identity in economics and provides a basic model for the discussion. This is a seminal work since there has been little study of the effect of identity on economic behaviour. The earlier paper, Akerlof (1997), concerns the analysis of social distance, which is essentially the study of one's position with respect to a reference point. This is then conceptualized and modelled in regards to its effect on decision-making.

Akerlof and Kranton (2000) presents a theoretical framework for analysing the economics of identity. A utility function is presented that includes the self-image or identity of the individual. Self-image is qualified by internal and external assignment of characteristic prescriptions. This also includes a person's consumer and producer identity. Meaning, one's market actions are premised on their identity. Although both the individually and socially determined identity are significant, the latter will be of the most concern. This is

due to the focus of the one way causation of group behaviour on the individual. An important note is that if one is looking at the influence of identity then it must be in a specific context wherein the identities of people are agreed among the population. Otherwise, the social effects of a person's identity would be random. Although there will always be those with marginal perceptions, it is sought to have a population where they are outliers.

This research is relevant here since rural communities are likely to be more homogeneous. Thus, accurate social identification of individuals is more probable. The authors also present the concept of identity externalities. This is similar to social norms because it is based on the idea that those that share identities will make the same choices, which is essentially the maintenance of one's socially expected actions. Basically, this is the identification of reference groups, which is the locus of social interactions. As explained previously, the identification of social groups determines their choice. If a farmer identifies with a certain group that restrict themselves to a prescribed choice set, then they will adapt that choice set as well. There is also the situation wherein a person is born into an identity predisposed to having low utility. In this case, they might seek to adopt the choice set of a preferred reference group in order to transform their identity. Understanding the group's choice set can be critical in discerning how to influence that group to make a certain choice, because the barriers or complements one will encounter with respect to the cause of a new choice must be understood.

Providing another analysis of identity, Akerlof investigates social distance and decisions. These concepts are linked to identity since they are components of specifying a person's societal role. Akerlof (1997) provides a conceptual and utility model derivation of social distance and decision. Social distance is essentially the same as position within the network literature. It is modelled with respect to the utility derived from different points of social distance. As distance decreases between two agents, attraction increases and vice versa. A central assumption of the model is that an agent must base its decision on the expected positions of its potential trading partners when choosing its subsequent social position. The primary distinction that is made between economic and social decisions is that social decisions have social consequences whereas the former do not. Social decision is basically used as the overarching concept for any alteration of an individuals' social role.

The main point of the analysis is that nonconformists are in a state of disutility as compared to conformists. This means that those that maintain an expected level of status are in social equilibrium. One of the findings of the model is that there are multiple equilibria. This occurs when one's status level exceeds social equilibrium. In social equilibrium, one's status position equals the mean of the group's. Since achieving a level of status beyond that set by the social equilibrium is utility enhancing, new equilibria will occur at each point above the observed social equilibrium. An additional concern for the seeking of status is the negative social externalities. Due to the exceptional resources that have to be devoted to increasing social status, consequent anti-social behaviour can damage social capital. This can be one of the negatives in pursuing access to and/or resources for higher position. This could occur in farming if a farmer devotes their time for socializing to extra utility maximizing activities. More specifically, this view supports

that farmer's social utility is negatively related to seeking social status. Hence, this would dissuade farmers from exerting the effort to innovate. However, this lacks cultural context. For example, it is possible that those who seek to improve their welfare through exceptional labour could be lauded, and realize a significant increase in their social utility.

2.3.3 Position

To reinforce the importance of social definition, the concept of position is presented here. Position is based on structural equivalence, which regards the structural symmetry of actors. In basic terms, this is the relationship of the connections of actors to the other actors in the network. It can also be thought of as a principal-agent relationship; however, the primary idea is the symmetry of relations and behaviour with the other actors in one's network. Its importance is due to position being a strong determinant of receiving or exerting influence. Borgatti and Everett (1992) is a paper that deconstructs the meaning of position. Since different authors provide different definitions for position, the paper seeks to find common concepts that underlie the various definitions. Moreover, it provides a strategic review of the position literature. The earlier paper, Burt (1976), is another seminal work. It analyses position based on cluster and distance analysis. Meaning, those of the same distance and cluster are structurally symmetric. The main idea underlying the author's definition of position is structural equivalence.

Borgatti and Everett (1992) investigates the effects of position and structure in social network analysis. Most of the paper concentrates on the comparison between structural equivalence and isomorphism.[17] The purpose of the paper is to prove that these two structural types underpin empirical network analysis. Those that are structurally equivalent have the same influence within the network. In the situation of innovation adoption, those that have a higher position or stronger influence in the network are assumed to be more able to adopt. This could be due to education, greater complementary resources, skill, etc. that enable both a higher position within the network and a greater ability to adopt a technology. Isomorphisms can be applied in adoption analysis through the comparisons of different communities. If two communities have almost the same network structure, then the method of introduction in one community could prospectively be applied in the other because of the analogous structure. It is deemed that within the literature that many published works wrongly apply these two types of network relations and often create an amalgamation of the two, resulting in incorrect analysis. One of the features of this paper is to stray away from popular views in the literature on the respective structural definitions in order to properly redefine them. For the literature as a whole, this paper is important because it redefines and provides evidence for structural equivalence and isomorphism as the main structures for observed network analysis. Furthermore, the paper could be significant in defining network structures with respect to agricultural innovation among small farmers through the analysis of position.

Burt (1976) is a theoretical work that conceptualizes position within social networks based on distance and hierarchical cluster analysis. The first section of the paper defines what

[17] Isomorphism regards a one-to-one mapping of objects between networks

position is within a network. An important idea within the paper is strong and weak equivalence of position. Strong equivalence is when the relations of two networks are the same and the distance between the respective actors is zero. For adoption, communities of strong equivalence are ideal since the influence of the social structure would be identical. This would remove the major factor of structural influence in determining adoption. Weak equivalence is when the relations are identical but the social distance is greater than zero. This scenario would make adoption more complicated, but only slightly, since the relations would be the same aside from social positions. It is shown that structural equivalence is stochastic and susceptible to variation. Additionally, the idea of primary position is interesting in that it illustrates that actors in particular positions have more interest in actors to whom they are structurally equivalent. The phenomenon of elitism or 'cultures of poverty' stem from this idea. Those who are highly skilled will maintain their status as they interact with those who will be able to facilitate their status. However, those who are poor will continue to languish in a resource-poor environment because those are the people that they identify with.

2.3.4 Efficiency

To understand the impediments to learning one must study efficiency, which analyses the variance in the flow of information through networks. It seeks to understand the barriers to the flow of information and how to reduce them. Inefficiency in network information inhibits the amount and timing of information flows. In the case of an innovation, if actors in a network do not have sufficient information to make a correct decision on adoption, then they would be more likely to make a decision that would have negative effects on their welfare. Moreover, timing is a critical issue in the adoption process because if actors do not receive information in a timely manner, then they may completely miss the opportunity to maximize the innovation's potential. The paper by Jackson and Wolinsky (1996) models the stability and efficiency of networks. It focuses primarily on understanding duration and the characteristics of formation. In addition, it seeks to understand the influence on the productivity of actors.

Jackson and Wolinsky provide a fundamental analytical structure for estimating the stability and efficiency of social and economic networks. Graph theory is the main instrument in the mathematical derivation of the model. An interesting point in this study is that strong efficiency indicates maximal total value, rather than Pareto-optimality. Efficiency is based on maximizing the value of information rather than the balance of information flows. For the individual this is certainly the case since each seeks the maximum return from the information. However, in adoption it may be different. Based on social interactions, it is possible that farmers will seek to maximize the return of information for their reference group instead of their marginal return due to multiplier effects (thus in turn increasing their marginal return).

A few different models are presented apart from the general model. First, the connections model represents individual communications. Second, the strong efficiency communications model illustrates a star relationship wherein there is a central actor or node that has superior information to its links. Third, connections models with side

payments are presented whereby there are actors in key positions that receive exceptional amounts of resources compared with other actors. Lastly, the co-author model demonstrates researchers where each actor's productivity is a function of its links. An interesting rule of this model is that the introduction of a new researcher decreases the strength of interactions with existing researchers. A similar result could occur in a farming community since the cost of interaction increases positively with network size. In this scenario adoption would be more probable and faster in a smaller community because the interactions are stronger.

2.3.5 Social Learning and Experimentation

In order to reduce the uncertainty of applying an innovation farmers must experiment with the technology, if other information sources are unavailable, before its complete application. Experimentation can aid and expedite the learning process by providing direction for what needs to be learned. Since experimentation is natural among farmers it is a significant area to study for understanding the social learning of innovations. Aghion et al. (1991) take a strict view of learning and separates learning into being adequate or inadequate. The purpose is to understand how experimentation optimizes learning in successful and unsuccessful circumstances in order to have a total understanding of the process. Another point of this analysis is that noise[18] is added in the model. This is one of the reasons why this paper was included, because it has the ability to account for barriers to learning, such as with poor farmers, which gives a more realistic representation of the learning and experimentation process.

Aghion et al. (1991) present a two-stage model of optimizing learning through experimentation. What is important about this model is that it accounts for noise in the learning process as opposed to strictly neoclassical models that are solely deterministic. To build this model the first stage encompasses a deterministic derivation and the second stage involves the inclusion of noise. Two different types of learning are taken into account: adequate and inadequate learning. Adequate learning is premised on the idea that there is a probability of one that agents will get enough information to achieve the true maximum payoff. Inadequate learning is when there is a probability of zero that the agent will attain adequate knowledge. Thus, the analysis of optimal learning is given a more encompassing view of the world by the inclusion of inadequate learning.

Within both of these types of learning an analysis of learning is illustrated by models defined by no noise or discounting, no discounting, and no noise. This is done in order to develop a more robust understanding of the effects of the NPV of information acquisition and the effect of abnormalities within the learning process. The main finding of the model is that the benefit of experimentation tends to go to zero in the long run. In general, the analysis of experimentation and learning is intriguing. For example, it is shown that there is a positive relationship between neighbourhood size and the experimentation cost. In real terms, this depends on the links of those in the neighbourhood. If there are strong links then the cost of learning would actually decrease as neighbourhood size increases, because

[18] Variance in the rate of acquiring information.

more information would develop and flow through a large neighbourhood. Moreover, this would reduce the incentive for experimentation because of the substantial and diverse information. In this scenario the cost of learning would decrease for farmers. The analysis of cost and noise are pertinent as they are predominant issues in acquiring information, particularly for resource-constrained farmers.

2.4 Conclusion

The objective of the literature review was to give as comprehensive background as possible, since the thesis draws its ideas from several subject areas. Since my analysis will be using myriad terms and concepts, I believed that presenting these works will provide a sufficient conceptual background to enable the reader to properly understand the material in the following chapters. The division of this chapter was meant to provide not only background but also focus. By highlighting the areas of significance in the agricultural innovation and social behaviour literature, the review acts as a guide to the potential issues in the estimation. For adoption it is important to understand the influence of risk, neighbourhood effects, and markets as these are also significant to social networks. Risk determines how an actor uses social networks to reduce uncertainty. Neighbourhood effects can potentially overlap social networks due to space or other exogenous characteristics. Finally, markets can determine social structures based on sharing privileged information. Drawing on these central aspects will help distinguish what constitutes a social influence.

Regarding social behaviour, since definition in this field is precarious it is important to state clearly the concepts of interests and highlight prospective empirical discussions. Otherwise, it is easy to become lost in a pool of concepts during the analysis. Understanding the separation of learning, interactions and networks creates clarity. Moreover, highlighting key concerns such as ‘embeddedness’, position, efficiency and experimentation shows what concerns to be mindful of. ‘Embeddedness’ is consistently commented on in social networks papers as the strength of ties concept and is powerful in showing the significance of relationships. This holds for position as well since knowing the structural points in hierarchies and other structures directly relates to innovation transfer. Other concepts such as efficiency are also significant, as the barriers to diffusion determine the innovation’s viability. Additionally, experimentation is critical to understanding learning because without knowing if someone is teaching themselves it is equally difficult to ascertain if they are taught by others.

In the next chapter we give an extensive review of the data generation process, which concerns an intricate detailing of the data collection and instrument design.

CHAPTER 3

Data Generation Process

3. Introduction

This chapter reviews the data generation process. It details the methods and instruments that were employed and explains their significance to network analysis. There are two sections detailing the quantitative data process. The first concerns the general design of the data collection and the second reviews the specifics of the survey questionnaire. The latter will be particularly extensive as it will delve into the particulars of relevance to network effects. A third and final section describes the qualitative study.

The instruments were designed specifically to correct for network estimation issues (Durlauf, 2001; Durlauf and Fafchamps, 2004; Fafchamps and Gubert, 2007). The most salient concerns are endogeneity, self-selection, and behavioural network reflection. Trying to understand the state of social networks in a community is a daunting task (de Weerdt, 2002; Fafchamps and Lund, 2003; Bandiera and Rasul, 2006; Fafchamps and Gubert, 2007; Van den Broeck and Dercon, 2011). Not only must the common characteristics that instigate linkages be determined, but also sufficient trust must be developed with the community in order to retrieve the information about their interactions. The establishment of this trust was also facilitated by each respondent signing a consent and confidentiality agreement to ensure that their identity is protected.

For the enumeration, I kept my distance from the government due to farmers' distrust and suspicion of government. However, I needed simultaneously to show that I had some relationship with it, to give the impression that I was recognized by a body that they were familiar with. Thus, multiple identities had to be assumed. This sensitivity in particular is why it was important to have an understanding of the interviewees themselves before administering the network questionnaire. The substantial qualitative work which was carried out, as well as the adoption panel, gave me an opportunity to develop an intimate understanding of the community and the farmers. Sufficient effort must be made in the qualitative data collection to ensure that there is an intimate understanding of all the essential social connections in the community (de Weerdt, 2002). Moreover, spatial concerns should also be taken into account. There are also other characteristics that must be recognized and will be unique to each situation, such as community ties, history and farmer personalities that require the enumerator to tailor questions.

The instruments were divided into two groups of questions to determine the characteristics that were of most influence: social and non-social instigators. The former corresponds to behaviour that was instigated by social interactions and the latter to those variables capturing non-social characteristics. It is essential to define the spheres of influence for social interactions and to structure them into hierarchical relationships to provide interaction boundaries, particularly with respect to adoption and learning. Three conceptual tiers were used in the design of the questionnaire: social/non-social influence;

internal/external influence; and financial/non-financial influence. As stated previously, the main goal of the questionnaire was to isolate the network effects and intra-community interactions.

3.1 Identification Concerns

Endogeneity occurs when farmers form groups based on a common interest (Fafchamps, 2004). In this scenario the group phenomenon that coalesces actors into adopting the behaviour is considered, not the influence of social ties. Thus the relationship is not evaluated properly. Methods have been developed to correct for endogeneity, such as using instrumental variables in order to capture the group effect. However, because the data set is expansive, in that it captures a wide array of information influential to adoption, the characteristics causing endogeneity may have been included. One of the main variables that could be central to this is connection to extension and formal groups that have assisted in training.

In the qualitative study it was noted in almost all in-depth interviews that there was no preference socially with respect to their information source. The only thing that was important was the trust in that person's level of knowledge. This indicates that defined social entities are not of particular importance in securing information. In-depth interviews were used to try to identify networks that may be relevant to information flows. Nine networks were defined by the study.

There may also be endogeneity based on a common link due to extension's influence on adoption. For example, data was collected on teachers for sweet potato planting and IPM training. This common link may be important to the adoption of the innovation; even if the person known as a teacher in the community is not a teacher to the respondent, they would still have influence. Spatial locations may be another indicator, whether with regard to the districts of the farmer's respective home and field or the specific field locations mapped using GIS. This seems to be a strong determinant of interaction since many farmers do not have transportation and rely on walking, which prevents them from going to other districts in the research area. Another indicator may be market access;those that have noted better market access might have higher crop quality (possibly due to IPM adoption). This same variable is also correlated to pest damage, so those with lower pest damage are possibly a cause of endogeneity.

With respect to the data there is partial information on some of the formal groups in the community. There were three formal farmer groups in the community. Since only a sample was taken there is also partial information on group participation. One of these groups, ASSP, certainly was influential to innovation diffusion, but almost all the members from the group were enumerated.

Although endogeneity is presented above as a problem it also has another position in network effects estimation. For example, in some social effects estimations the average behaviour of the groups is taken as the treatment, thus the behaviour is endogenous because it varies with the average choice of the network or group (Manski, 1993). However, for other methods such as dyadic regression this is not the case as dyadic

relationships are being estimated and not group behaviour as expected. The endogenous relationship can indicate whether adoption is born out of an overarching group phenomenon rather than interactions within the group.

Self-selection occurs when there is sample bias, meaning that those in the sample are inclined to adopt (Asfaw, 2010). Meaning, the sample is not random, but is an attribute particular to those actors. This may be a problem but it seems that there is substantial variation with respect to adoption behaviour. As noted before, a census was attempted but unforeseen problems caused attrition. Hence, attrition bias was of concern but was later attributed to an endogeneity problem due to common characteristics (primarily marijuana farmers and minimal or absent RADA interaction) amongst the dropouts that were related to the treatment of extension. Tests such as the Heckman test are employed to determine if selection is an issue.

The next issue is the reflection problem, as denoted by Manski (1993). A way to control for this is by collecting the point in time when these interactions occurred, such as described in Manski's work. However, more recent literature has determined that in order to correct for simultaneity it is not necessarily the temporal interaction that must be controlled for but the directional differentiation in the network effects (Moffitt, 2001; Lee, 2007; Bramoulle, Djebbari, and Fortin, 2009). As described in the literature review, there are three types of network effects: endogenous; exogenous; and correlated. These represent the full spectrum of network influence, as there is variation with the behaviour of the reference group, with their respective individual characteristics, and common environmental factors. Simultaneity is identified when the endogenous and exogenous effects have a perfect correlation thus if we can sufficiently specify the model using the network autoregressive specification; the endogeneity that occurs from the simultaneity should not influence the estimation. This is likely to be satisfied as we have a purpose–built data set to correct for such issues.

It could be argued that essentially any interference in the exchange of behaviour could act as an impediment to direction. For example, if it can be proved that the exogenous characteristics of the actors creates a socially unequal relationship, then it could be noted that the network is directing the relationship so it is unlikely that the actor is imposing his behaviour on the network; rather, the network is imposing on him. These are merely proxies for capturing the actual characteristics of the exchange. However, they could be helpful in giving a more robust understanding of the possible influences in the relationship. This could add some interesting aspects into why the relationship is occurring and if there could be other indicators that could proxy for the actual interaction properties.

One of the primary issues with network effects studies is defining the network boundary (Fafchamps and Gubert, 2007). Usually boundary definition is quite subjective because it depends on how the researcher wants to define the characteristics for having a link. Luckily in this study it is quite simple because the primary characteristic for link formation is farming information transfer. Consequently, in order to define the network boundary, a survey was conducted that required respondents to name the farmers from whom they receive farming information and their respective field district. A confidence interval was created for the field districts for the respective information links and those

farmers that planted in districts outside of the interval were deemed as outside the information network. Those farmers that planted in districts outside the network area were not included in the sweet potato farmer census list for the main survey.

Another important aspect of network specification is the identification of social entities within the research area. This was done in two ways. One is in the quantitative study and the other is in the qualitative. Only the former will be discussed here. To tease out the social groups each respondent in the adoption panel questionnaire was asked to name any farming group that they participate in and any other farming groups that they know of. Now what is of concern is that a temporal restriction was not made with respect to group membership. This was done strategically because a similar question was going to be asked with a temporal restriction in the main survey, so this was avoided to reduce respondent fatigue. Everyone was also asked to name any non-farming groups that they were members of and any others that they were aware of. The general purpose of this was to find the organized groups and then target these in the qualitative study in order to understand what their influence was in the community, in farming, and in inter-group interactions. What matters about uncovering such information is to know the spheres of social influence that could be important to the formation of links. As noted throughout the social effects literature, it is central to understand this to get an idea of what structural relationships there may be within the groups and hence to determine the significance of inferred relationships. Without this information it would be impossible to have a real understanding of why certain groups are significant to behaviour as compared with others and what inference is actually capturing with respect to the group's influence.

3.2 Adoption Panel and Census

A census was performed using an informal informant that had an exceptionally intimate knowledge of the community due to being a member since birth (over forty years), an irrigation worker, and a farmer. The census was performed as a part of the fielding of the adoption panel. In the end a census of 98 people was created with 95 people surveyed. The census and survey were performed in September 2008 as well as a pilot. In addition, some were surveyed during the period of the main survey as they could not be located during the initial survey. In February 2009 the census was updated to include the alias of every farmer, when it came to be known that many farmers do not know each others' official names, but only their aliases. Consequently, every farmer was asked this.

This questionnaire was short and designed to collect a few socio-economic variables as well as pest damage, planting technique and network information. The primary purpose was to ensure that there was sufficient variation in adoption to guarantee that the study was credible. Secondly, it was meant to extract the influence of pest damage on the crop, which would be a main incentive for adoption. Third, a panel was taken in order to understand the adoption behaviour during the adoption period as well as before it. Fourth, the network section extracted the information to determine the network boundary and membership of any formal groups. Lastly, a few questions were asked about the respondents' consent to participate in the main survey in order to determine the potential

number of respondents. Only the first four sections will be discussed, as they are pertinent to the study's content.

Household

Four questions were given here: age; education; names of schools attended and livelihood. This rather basic information was asked for to assess the effect of these factors on adoption and learning. RADA suspected that these were significant factors in adoption. They thought that older farmers were less likely to adopt because they were primarily focused on subsistence rather than commercial farming. In addition, they assumed that the less educated were less inclined to adopt and learn about the innovation. The livelihood question was included to see whether or not the respondents were part-time farmers, since it was suspected that part-time farmers would be less inclined to adopt as they would have alternative income sources. This data also helps to identify social stratification which could be significant in understanding the access to training and information that would be central to adoption.

Pest Damage

A few more questions were given in the pest damage section. The first was about when they first used the pheromone traps. This was asked about instead of the entire technology because it would have been impossible for them to recall when they simultaneously adopted the primary IPM methods. It acted as a proxy, but since the pheromone trap was a centrepiece of the IPM training, it is likely that it could be indicative of learning about the entirety of the technology. This was followed by a question about the amount of pest damage their last harvest sustained and whether they sold that harvest to the domestic and/ or export market. Then the farmer was asked to rank the pests that had damaged their crop. This was done by presenting them with pictures (provided by Caribbean Agricultural Research and Development Institute [CARDI]) of the pests that most commonly damage sweet potato in the country. Lastly, I asked them to rank the barriers against investing into pest management for sweet potato. This information helps determine the innovation's need and other farmer characteristics. For example, if a farmer has little damage, but adopts this portrays a cautious and thorough farmer that has a high value for his crop. Such farmers would be more likely to teach others because of his level of dedication.

Planting Techniques

This was the main section of the questionnaire. Essentially, I had a comprehensive list of planting techniques that included IPM techniques. This was compiled based on information from the JMOA, RADA, and CARDI. For the years 2003 through 2008 the respondents were asked what techniques they applied for each planting. I also asked whether they applied any of these techniques before 2003 since that was the year that IPM training began.

Networks

This part was the most important because it established the farming advice networks in the community as well as their locations. Moreover, any participation in farming and non-farming groups in the study area was collected. The purpose of this was to define the interaction area for farming advice as well as to identify interactions for targeting in the qualitative study and main survey. In addition, two questions were included about Rotating Credit Association (RCA) and labour sharing group participation, to understand the significance of these once prominent risk sharing organizations. This would give a general idea of the strength of ties in the community since these groups require strong measures of trust and respect amongst its members.

3.3 Main Survey

Out of the 95 census respondents 64 were enumerated and 58 completed the questionnaire in its entirety. Enumeration was from February to the end of May 2009.

The enumeration was done entirely by me because of trust. I was already familiar with the community since I had been working with them for almost half a year. In addition, the quality of labour in Jamaica is low in general, particularly if the work is for foreigners, since many expect high wages and little work. However the determining factor was the trust issue because the sensitivity of the questionnaire. Another concern is that enumerators would not have knowledge of the community since they would not be able to determine if people were lying. Since I already had an understanding of the interactions, positions and behaviours of farmers I could perceive whether or not the respondents were being truthful. Another problem encountered was the widespread planting of marijuana. Although I knew that this community cultivated marijuana, I did not know its extent until I began exploring as I walked through farms in the community. This was one of the primary reasons that many farmers were doubtful about giving me information; they suspected that I was there to investigate marijuana production. In addition, the army unfortunately began its marijuana eradication campaign during enumeration, so there was increased tension with the community. As the questionnaire including detailed questions on land and property as well as GIS mapping of land holdings, there was more scepticism, because the government was pursuing a draconian fiscal restructuring in response to the economic crisis and there was much discussion about tax increases. Although few people in the area held land legally, many were scared that the government was going to dramatically increase property taxes. These were the primary reasons why there was a substantial attrition in the census population.

In order to check the validity of the survey a pilot was performed in adjacent communities. Only five surveys were tested but that was due to the lack of sweet potato farmers in adjacent districts. It was decided that it was best to pilot the survey in nearby communities to ensure consistency.

3.3.1 Main Survey Design

The main survey instrument was extensive (this may be another reason why several respondents dropped out of the study). There are ten sections to the instrument: Household; Community History; Land; Technique Use; IPM Test; Extension Influence; Welfare; Market Access; Social Interactions; Networks. The instrument implemented by Joachim de Weerdt in Nyakatoke, Tanzania, was used for consultation (de Weerdt, 2002).[19] In this section the reasoning behind each section and the questions is explained, with a focus on network effects.

As stated in the previous sections the study was designed to correct for a few inferential issues: endogeneity; self-selection; and behavioural network reflection. These are issues that were meant to be corrected not only by the general design of the study but also from the instrument design. These issues, in addition to the themes of study and research objective, will be consistently touched upon as we transverse the questionnaire. The central concern for the survey was temporal consistency and reference since there was a temporal restriction for the period of interest. The discussion will focus on relevance to network effects. General design notes will be discussed and the questions themselves will follow. The purpose of this section is to highlight the most significant relationships and issues relevant to the respective questions in each survey section.

General

Unlike previous network effects and innovation adoption studies, farmers and not households are used as the observation. The reason is that a couple of households had independent farmers. Most importantly, they had independent farm economies (aside from labour sharing). This is a significant difference because household observations have different assumptions. For example, for households it must be assumed that there is intra-household information pooling, meaning that there is uninhibited information exchange amongst household members. This can be a significant restriction depending on the circumstances of the farmers in the household (e.g. migrant farm workers, other reasons for migration, household withdrawal, etc.) because it assumes that the household members have consistent interaction over the adoption period. Moreover it complicates the network study because the networks are household and not individual actor specific, which completely changes the dynamics of social interactions. Studies that use household observations cannot confidently assert who is actually interacting, since it is actually subgraphs that are interacting. This substantially increases the difficulty of proving such assertions since static interactions amongst subgraphs have to be proved, with multiple and most importantly dynamic actors. This issue of comparability applies to all other variables as well.

Another important instrument attribute is the use of a roster. This is common in the social networks literature, but it has only been employed once in network effects and innovation adoption studies (de Weerdt). It is critical to administer rosters to respondents because not

[19] I am very grateful to Joachim de Weerdt for allowing me to reference his survey for this study. It must be noted that I developed a large majority of the instrument.

having a social boundary instantly renders the study unreliable; the responses cannot be compared, as the interaction area would vary amongst them. In addition, the roster length has to be reasonable to administer (the number of networks and questions utilizing the roster must be taken into consideration) in order to minimize respondent attrition. An additional issue is that if this study is conducted in a poor community. illiteracy has to be accounted for. This can substantially increase the administration time (by hours for people with large networks) because the roster will have to be read in its entirety for each network. Twenty-eight people out of the 58 who completed the full survey were literate, thus for all the remaining people the names were read aloud. This might pose a difficulty in finding professional enumerators who will not shirk from this extraordinarily tedious task.

A final point regarding the general design is the organization of the survey. The sections were placed in the following order: Household; Community History; Land; Technique Use; IPM Test; Extension Influence; Welfare; Market Access; Social Interactions; Networks. The most sensitive sections of the survey, welfare and networks, were left for the end in order to develop trust with the respondent. The less sensitive sections, household and land, were placed at the beginning; the latter being more sensitive than the former, the community history section was placed between these sections as a mini reprieve. These three were placed at the start to provide a substantial reprieve before the exceptionally sensitive welfare and network sections. Between these sections all the agricultural sections were placed (e.g. technique adoption, IPM test, extension). Another reprieve was put between welfare and networks using the market access, and social interaction (the latter differs from networks in that it focuses on formal group attributes) sections.

3.3.2 Household

A number of questions were administered regarding household characteristics as well as welfare allocation and income, and sweet potato labour allocation.

The purpose of household characteristics is simply to look at welfare responsibility (Alene and Manyong, 2007; Yamauchi, 2007; Asfaw, 2010). This can illustrate whether farmers' stress from household obligations influences social choice. This can occur in different ways. For example, it is possible that social insurance could be positively related to greater child and/or adult support since people may change their social interactions with respect to risk (Fafchamps and Gubert, 2007). Furthermore the significance could vary amongst the interaction groups. The same logic applies for the number of children that farmers send to school. Other welfare indicators are remittances, medical payments, and funerals/weddings. Intra-household influences of labour allocation and farming experience of adult farmers as well as sweet potato experience are collected. In addition it is recorded whether or not they help each other plant sweet potato together or separately. This data can be used to look at the possible influence of the density of actor planting experience since they are in the same household. However, this may be problematic since further data (e.g. most were not enumerated since they did not plant on individual plots) is not collected on other farmers in the household that assisted with planting.

3.3.3 Community History

This section enquires about each farmer's attachment to the community. There are questions regarding where the farmer was born and, if they were born in the area, which district they were born in, as well as their partner. The amount of family members in the area was also recorded, and any times of migration greater than 12 months. Other questions concerned farming experience, sweet potato experience, their five most important crops in the last decade, and any other skills that support their livelihood.

It is important to understand the forces which hold an actor within a community (Agarwal, 1983). How much family an actor has in the community and whether or not their family is originally from the area can indicate partiality to the community (Bekele and Lars, 2003; Bandiera and Rasul, 2006; Cai et al., 2008). Furthermore, it can indicate whether originating in the area is important to the size of networks and link characteristics. It was necessary to collect this information for the partner as well, since they are assumed to act as a bridge for their network links. Other information that was collected regarded their time in the community. Again this is indicative of their tie to the community, since those who have lived in the community for their entire lives would probably have closer ties than those who have migrated for long periods (Agarwal, 1983). Something that is critical in understanding interaction is farming and sweet potato experience, as well as when they began planting sweet potato. This can illustrate that older farmers tend to interact more, and this could show a concentration of knowledge within the population. This applies for sweet potato experience as well.

3.3.4 Land

One of the key reasons for collecting information on land was to analyse wealth disparities in adoption (Berger, 2001; Bekele and Drake, 2003). Based on our interactions in the community, it is believed that this is highly unlikely. Other reasons included tenure, and spatio-temporal influences. Most farmers in the community sharecrop, squat and rent. There are only a few farmers who own land and there are even fewer who have titles. This has influences on credit access since it is strongly preferred to have a title. There was a great fear of credit in general in the community and many noted how taking out credit resulted in a virtual collapse of their welfare level.

One of the most important aspects is that of the spatio-temporal. This is likely to be a significant influence on land effects since, those that planted more frequently and closer together seemed to be more inclined to have the same behaviour. More specifically this data may indicate spatial clustering (and possibly temporal clustering) since there are several districts within the research area. A limiting factor in the spatial analysis is that GIS data was collected only for the fields, not for the homes. This was done strategically; it would have been too sensitive to collect GIS data for homes, as possibly all the participants would have reneged. The surveys were conducted in an area mostly comprised of fields, so asking people if I could meet them at their home would have aroused suspicion. However, the home districts for all participants can be used as a suitable proxy. Another important variable collected was how much was planted on each respective field during each year in the adoption period. This will indicate planting frequency and possible

reinforcement of learning. Other variables collected were: general time of plot use, plot size, property worth, irrigation, leasing, and sweet potato planting.

Land is possibly one of the most important influences on social interaction (Goldstein and Udry, 2008). Regarding land wealth, land availability, space, temporal, and spatio-temporal arrangement there are a number of interesting network relationships that can be drawn. Land wealth could have a few different effects. For example, those that have more land may cluster socially, hence there would be a core group of people who interact and share information (Hogset, 2005). This could represent position as well, in that those who are in the group (clique) could hold a higher status than others. Moreover, it could indicate vertical structures in general among the networks. Also, where the land is located could be significant. For example, those people who have a small number of large holdings may have different linkages from those who have many small holdings. Furthermore, their tenure may be influential as well.

One issue that was brought to my attention by a few farmers was the availability of land. Sometimes farmers simply do not have the land available to plant a crop. This means those who have more plots will be at an advantage with respect not only to land quality, but also to social capital (Goldstein and Udry, 2008). Those who have multiple plots have a larger interaction space and have a higher probability of learning from others.

Space, as noted before, is most likely to be one of the key indicators of social interaction (Case, 1992; Nyblom et al., 2003). However, there are other characteristics that may be important, such as extension interaction. Those who have fields located in the Hounslow district and in a particular area of Ridgepen are most likely to have disproportionate extension interaction because the concentration of fields in those districts makes them easy to service. This may cause a concentration of knowledge because famers who have fields located in those areas will be at an advantage and, due to this bias, could possibly serve as key information nodes in the community.

Temporally the planting frequency and plot size may give an idea of years of high prices. For example, 2005 was a year when there was an exceptionally high sweet potato price and this year has the most sweet potato planted out of all in the adoption period. Also, this year may be a time of herding; because everyone is trying to capture the best price, they could also try to find the best information. This could be illustrated by a dynamic change in the networks, if the temporal interaction data is able to show this.

3.3.5 Technique Use

This is one of the key sections (others being IPM Test, Extension Influence, Social Interactions, Land and Networks). The section collects the information on the adoption of IPM techniques. For each of the nine techniques within IPM, ten respective questions are asked. Then there are further questions on the planting of a cutting nursery, chemical reliance as opposed to IPM, the need of market or IPM knowledge, and panels on planting techniques. The purpose of the adoption questions is to understand if each aspect of IPM was learned, when it was learned, if it was learned socially and from whom, if the technique was adopted and when, if not adopted then why, if it was experimented with,

and the primary influence of adoption. Essentially the purpose is to understand the difference between individual and social learning, and most importantly to capture the times and primary influences of adoption. The relationships will be explained in greater detail in the empirical chapters. Other questions were included to find out whether the farmers understand the purpose of the techniques, as well as to see those who were especially innovative and who planted cutting nurseries. This was then followed by the technique panels (spray rotation, planting next to old fields, pest scouting, and pest barriers).

The adoption table was simply to find out whether the techniques are learned primarily by the farmers themselves or from others, and, moreover, whether from sources or people outside the community (Bandiera and Rasul, 2006). This directly accounts for the influence and direction of adoption. Something that might be interesting to look at is learning and temporal variation. Since there are some farmers that learned most or all techniques in the same year and others that learned techniques at separate times, this may give some clues about the temporal variation in network learning. This is something that I found interesting during the survey, because there were a few instances where farmers learned after they stopped planting sweet potato. They did not pursue the information while they were planting, which could indicate the relative importance of innovation or disparate network relationships. For example, it could signal that these farmers did not fully seek out the best information about the technology, but used what was immediately available to them. This could be analysed by looking at the relationships of adoption years, farming experience, sweet potato experience and various other network attributes, to try to understand what network characteristics could be causing these disparities in adoption.

3.3.6 IPM Test

This section was designed by a plant scientist at RADA (she also carried out IPM training in the community). The test was developed based on the applied knowledge that was taught to the farmers by RADA plant scientists and extension officers[20]. The purpose of this is to get a direct understanding of the farmers' knowledge. This is opposed to proxies that are often used such as crop production or revenue. It was developed in order to directly capture whether or not the farmers became competent in the information that they were taught by extension officers. The test is practical rather than academic. In addition, it was created to determine whether farmers understand the innovation's application. The test is also used to judge innovation effectiveness as any correlation between innovation competency and export markets will be indicative of this. The reason for this is that the crop was developed to expand access to the sweet potato export market, which has higher quality standards. If export market access is shown to be strongly positive and correlated to innovation competency then this will show that the innovation is effective.

Most of the section focuses on the maintenance of pheromone traps since this is the newest and most sophisticated technique within IPM. The other techniques are simple and have

[20] A weighted scoring was developed for the test by a research director at the Bodles National Agricultural Research Centre that was instrumental in the country's IPM programme

been introduced in previous years, separate from IPM's introduction. Thus they were given a more ancillary place in the test. The score on the IPM test could illustrate divisions based on knowledge levels; those that have higher scores may interact more with formal training sources or with those people noted as teachers of IPM within the community. It is suspected that there is a core group of farmers with higher knowledge levels (particularly those who are members of ASSP). This is important to identify as it can be useful in identifying endogeneity. Whether there will be particular networks significant to knowledge levels cannot be foreseen. Market sharing may be significant, since the sharing of markets may indicate close farming relationships due to the protectiveness of markets. In addition, there may be implications with respect to heterogeneity. As noted before, heterogeneity can hasten and/or induce behavioural change since observing of the attainment of a higher level of utility by groups of lesser utility can instigate behavioural change. This same concept can be applied to learning. Higher utility can be viewed in a number of ways, such as trust levels and regard for quality of advice. Since the collection of this data, they are the foreseeable identifiers for heterogeneity. Moreover, there could be multiple links of heterogeneity influencing learning. For example, there could be interaction amongst trust, advice respect, learning levels, and extension regarding link heterogeneity. This means that networks could develop based on heterogeneity. Hence, those who are not as knowledgeable are attracted to those who are. It could even be possible to look at this spatially, in order to understand whether network heterogeneity is also influenced by spatial configuration.

3.3.7 Extension Influence

Understanding the extent of foreign influence on technology adoption is important to differentiating farmer-to-farmer network influence (Hogset, 2005a; Hogset, 2005b; Hartwich, 2007). The pervading theme is the separation of community network interactions from external community interactions (Goldstein and Udry, 2008). This section details questions about the most significant external influence, which is RADA. The questions concern the interactions that farmers have with RADA, in order to understand the relationship that they have had over the adoption period. There are a number of aspects of the relationship that are of interest: trust; frequency of general advice; frequency of IPM advice; way of interaction; personal bias; group training; other formal IPM information sources; technical advice preference; market advice preference; and availability of primary IPM component.

The infiltration of extension into the sphere of influence for interaction is central in determining the influence of community network interactions on adoption and learning (Hogset, 2005a; Hogset, 2005b; Hartwich, 2007). The viewpoint of the influence of extension on networks is how the extension service penetrates the community by acting as the lead advisor for the technology. Although it would be assumed that having introduced the technology to the community, extension officers would be the primary advisors, farmers mistrust them or feel threatened by their superior status and this can impede advisory interaction. Instead, farmers seek out other farmers whom they trust and can communicate with, to learn about the innovation. This also raises the concern of the perception of extension officers and whether or not they are seen as technical advisors. If

they are not, then they are not presenting themselves properly to the community. This is something that needs to be understood; and the relationships for analysis are given above. The relationships revolve around the following concepts: frequency; density; and closeness.

3.3.8 Welfare

This section uses standard questioning for welfare measures similar to the Living Standards Measurement Study (LSMS). The only difference is the inclusion of irrigation debts as a welfare measure. This is particular to this community since it is endowed with an irrigation scheme. Moreover it was understood to be a reliable and effective indicator since full payment of irrigation fees is rare. There are four parts to the section: debts; livestock; house characteristics; and household durables. The purpose is to comprehensively capture the variation in welfare levels. There are a few variables that might have exceptional importance aside from the irrigation debt. Bank debt is something that was repeatedly noted as a great impediment and/or burden that could substantially diminish a farmer's welfare level. For example, some noted that their land had been seized by the bank or they had to sell their high value assets. This would put a substantial strain on the farm economy. Loss of assets, such as livestock, would cause this same scenario. Owning a washing machine, car, truck, and/or dryer are prospective significant indicators of wealth as they are expensive durables that are highly desirable. Moreover, having hurricane resistant roofing is another widely viewed indicator of wealth. Lastly, living in a wooden house indicates a low welfare level since a wooden house is highly susceptible to hurricane damage and only built if cement block is too expensive.

The simple objective of welfare indicators is to discover if welfare characteristics are significant to networks (Macours and Vakis, 2008). This characteristic can manifest itself in many ways. In this context welfare represents a farmer's financial resource level. Networks can even be defined based on welfare levels (Macours and Vakis, 2008). For example, there could be correlations between kinship networks and welfare because those that have extensive familial ties can have more and stronger resource sharing connections (land, markets, labour, etc.). In general it can cause issues of clustering which can cause endogeneity in the estimation. If there is a group of farmers at a certain welfare level that have privileged access to information, there could be issues of endogeneity, since the impetus for adoption would be due to this preferential access (Fafchamps, 2004). This phenomenon would instigate the actors to coalesce through the adoption behaviour. This is one of the more salient issues with respect to policy since subsidies through extension are often predicated on wealth (not only financial but in terms of any resource that represents welfare). Such knowledge would be influential in improving targeting. There are numerous topological relations that could be drawn upon in order to demonstrate the influence of welfare on network characteristics (Macours and Vakis, 2008). Moreover, there is the issue of the influence of variance in welfare levels on topology and network relations. It is often cited in the literature that one of the key phenomena in social interactions is heterogeneity (Munshi, 2004). The rest of this section concerns household characteristics and durables that are central welfare indicators. Transportation assets

within the durables section are significant to linking with network size (number of ties) and interaction frequency.

3.3.9 Market Access

Market access could be a principal determinant of network interaction (Spielman et al., 2008). During the initial enumeration many people noted that markets are scarce as there are high levels of secrecy about to market information. However, after performing the qualitative study it was found that this was not especially the case and that markets were shared.

People that have unique market access, particularly to the export market, would possibly have much higher knowledge levels since traders are attracted to the most capable farmers. If farmers make sure to control welfare increasing information (market and innovation) by only releasing to certain people then cliques of information could develop. This would concentrate the market because cliques of farmers with better information and innovations would control it due to better yields and crop quality. This would prevent farmers from outside the cliques from penetrating the market.

In addition, a major concern with this data is that some traders' names may not have been given because of their involvement with the marijuana trade. It came to be understood that there are some traders who trade both legal and illegal crops. This may cause the data to be misleading, but it is possible that only a few traders trade in both areas. Asides from this issue the most significant things to be captured in this section were the perceptions of the market quality during this time, the most significant people to contact for market information, the approximate number of buyers for local and export, and the names of these people.

As stated previously a main concern is the formation of information cliques based on market access (Spielman et al., 2008). Although this is ostensibly the most salient concern there are several others to take into account. The impetus for innovation adoption is to increase market access based on crop quality, so farmers seek the best possible information in order to increase their market potential. To do this they must optimize their information links.

The possibility of more detailed questioning for market interactions was investigated; but the quality of the data would have been poor since no records are kept and trading is very informal. The questioning sought to understand what farmers thought of their market access and whether they were able to sell their crops. This would give an idea of whether or not they are satisfied with their market access. Those who are satisfied could have particular links through family, labour, extension frequency, training, etc. that would connect them to networks that facilitate market access. This is directly related to the formation of information networks. Moreover, collecting the number of traders that the people know will give an understanding of how wide their network access is and its density for local and export markets.

Also their market perception will indicate the amount of their crop that could be sold. In addition it is important to understand whom farmers consult with to find traders. These

people could be the central nodes in distributing information as well as market access. Essentially the primary purpose of this section is to understand the connection between market access and information levels, since it is suspected that they are correlated due to the importance of crop quality. This same logic applies to the names of buyers and their market source (local or export).

3.3.10 Social Interactions

Here I was seeking to capture the formal group interactions (Hogset, 2005b). Formal groups consist of actors who are aware of their unique social identity. It is necessary to differentiate networks from groups for several reasons. First, the impetus for their formation creates contrasting incentives for maintaining the social identity. For formal groups there are spoken rules of engagement that must be complied with in order to maintain membership. Although informal networks can have similar rules, they are ambiguous since there is no universal agreement. First, these formal groups are exclusive and contiguous. Second, formal groups have an established structure in which hierarchies and defined positions determine each actor's set of behaviours. Third, there is a defined size, hence search costs are much lower. In general, what differentiates these groups is an acknowledged existence. Without this, all behaviours directly related to the network are based on assumptions rather than on openly recognized characteristics.

This section is quite simple. The questions concern the identification of teachers in the farming community, sweet potato labourer connections, participation in farming associated groups, field adjacency, and preference for joining a group based on a material incentive. Four formal networks were defined, based on information from the extension agency and the adoption panel.

What is most important about this section is isolating those people in the sample that are participants in a formal group (Hogset, 2005b). This is necessary because correlations must be tested with the groups to determine if networks are related to formal groups. Otherwise, it is impossible to know if the influence of the networks is really being tested. Also it is important to determine which social entity is more significant, because it is possible that there are correlations amongst them. Since it is essential to isolate the information source and the social entity through which it disseminates, this is critical. The section simply collects information on the formal groups of which farmers are members and how long they have been members, as well as the length of time that they have held any positions. This will give an idea of the structural implications of holding positions in formal groups as well as the temporal influence.

Another important issue is the identification of farming teachers in the area (Van den Broeck and Dercon, 2007). From the census list farmers must choose those people from whom they have received advice, but to whom they do not give advice. These must be identified to understand the hierarchies in the networks so that the vertical dissemination of information can be identified. It is possible that the networks could be dependent on the teachers, thus it is important to capture this element.

Somewhat ancillary, but suspected during the qualitative work, was the influence of labourer networks on the exchange of information. Since labourers are the ones that would be trained by the farmer and follow his stipulations they would be familiar with the techniques that are employed. Furthermore, they would spread this information to other people that they work for and other labourers.

Another suspicion was the recall by farmers of those people that they were adjacent to. Although it is recorded through GIS, the location of the farmers' fields was recorded to understand if farmers could actually recall planting next to one another, to test their emotional closeness. This is simply to see how significant people are to one another based on their intimate spatial arrangement.

A final interest was trying to determine whether or not people place their self-interest above others in the community and if they have a community spirit. Although only one question is given about this issue, it is an encompassing one. The question simply asks if they would prefer to receive a subsidy as an individual or through group membership. This gives an idea of whether people are interested in the idea of engaging in a group in order to receive a benefit. Moreover, it indicates whether people are willing to join a group even if they have an incentive. This could indicate the respect that people have for farming groups and their general affinity towards them. If it is favourable, that means that people could place more trust in these groups as opposed to informal networks. If not, there would be more interest in informal interaction. This is significant because the formal groups are central information centres. If there is little interest, this could have a negative influence on the development and stability of any future groups.

3.3.11 Networks

Nine informal networks were identified based on information gathered from the adoption panel and qualitative study: sweet potato IPM advice; planting material sharing; market sharing; hired labour; day for day; family; informal insurance; partners; and tool sharing. Each network list is primarily composed of a set of core questions common to each network link. All the networks and their relevance to the network themes (de Weerdt, 2002; Fafchamps and Lund, 2003; Bandiera and Rasul, 2006; Fafchamps and Gubert, 2007; Van den Broeck and Dercon, 2011) are discussed in this section. They are divided into two sections: Core Questions; and Network Specific Questions. This is to make the analysis more concise by intertwining the analysis of networks in the core question section and then analysing only those networks that have network specific questions.

Core Questions

he variables that are common to all network lists consist of the following: Network ID, Location– Home and Field Districts, Gender, Trust, Speaking Frequency, Years of Friendship[21] and Years of Interaction.[22]

Network ID simply collects the network number from the census list. Location, which regards the collection of districts, helps in understanding spatial relations. Gender implicitly gives insights into gender. Trust uses a scale for obtaining a direct measurement for tie strength. Speaking frequency is an additional measure for tie strength as well as the final two core questions: years of friendship and interaction.

There are a few different structural characteristics that encompass the core questions: frequency, tie strength, density, closeness, centrality, position, ego and direction.

Sweet Potato Advice

This network is the base network because it collects all those links that have given IPM advice to the respondent. The structural concerns of this network are central as it accounts directly for the innovation information flows. The key to understanding these flows is defining the structural characteristics that influence them. Listed above (in the first paragraph) are the primary influential characteristics.

Frequency represents the amount of interaction amongst actors as well as density. Those who receive information may do so on a regular basis or it may be a unique event. These responses will indicate the level of dependence amongst actors. For example, if there are numerous people that interact infrequently then it indicates the network's insignificance. This could be critical to showing the importance of information exchange and how the network can be targeted. Moreover, it can indicate the information exchange efficiency. Correlations amongst exogenous characteristics can also determine the reach amongst the actors (Dekker, 2004).

Planting Material Sharing

This network is expected to be large and dominated by weak ties as this behaviour is very common. It is often assumed that there is a correlation between density and the value of those entities within the network. However, it is foreseeable that there is a strategic reason for the network size such as risk aversion or targeting market segments based on the varieties. One important feature could be the directionality of exchange. If it is shown that there are a few actors that are sourced for planting material then this would show the influence of centrality in the network. Such characteristics could lead to further analysis

[21] The only exception is family networks. Since they have blood ties the relationship cannot be judged based on friendship due to the innate relation.
[22] As note 19.

regarding the interaction of planting material sharing and other actor characteristics, particularly with respect to pest management methods and their farming success.

Market Sharing

This network's structure is expected to be significant to the community's structure since a farmer's focus is market access. What is important is how farmers of position interact with the farming community as they are the financial gateways. For example, farmers that have weak gateway links are likely to have poor market access and know few traders. It is necessary to discover why this is. Central to this is discovering the frequency with which the actors interact, to see whether or not there is something determining their interaction pattern and hence their ability to access markets. Akin to this is the density of the network and the prevalence of centrality. If the networks are highly segmented with respect to market access, this will help to identify the barriers to interaction.

What will be of particular importance is the relation of the teachers and those that have strong market access. It is unlikely that this will be an ego-centred network since it seemed that market information is freely shared. Direction of the network links will indicate the market information flows and if there is a concentration in market information. Another significant interest is if there is a possible structural equivalence between market sharing and IPM advice. Since the market is based on crop quality it may be that those that supply sweet potato advice also supply market information. Consequently, these networks may coincide with one another. This is hoped for, as any isometric tendencies would be ideal in extension targeting.

Hired Labour

It is expected that hired labour would be a small network since the interviewed are primarily farmers and not labourers. Although farmers do hire other farmers for labour, it is uncommon. However, this needed to be captured since labour interaction would be quite important if there was a lively labour market amongst farmers (Conley and Udry, 2007). The frequency of interaction and network size will indicate if there is any concentration of hired labourers. There was a suspicion that the most successful farmers and those with the highest welfare status would seek skilled farmers for labour to ensure their crop quality. Also, farmers of similar welfare status may not hire one another because they may see it as belittling. Due to the hierarchical and status nature of the culture it was viewed that this may be significant.

An additional characteristic is the use of family. What is important about labour is that sweet potato is very prone to damage. This means first choice labourers would dominate the network and cause centralization. This may cause access problems since they are in high demand. Furthermore, the closeness and density of the network could prevent labour quality improvement. Since competition is needed to improve labour quality this may stifle the overall market value of the crops because farmers are unaware of the available labour.

Day for Day

Labour sharing, which is better known as 'Day for Day', is an old farming institution that was based on a group of famers sharing group labour through a rotational agreement. The purpose of the organization is to reduce labour costs and to ensure labour quality. Labour sharing was suspected to be of substantial importance to the community if it was prevalent. Since it necessitates a high level of trust and reciprocity it could act as a benchmark for strength of ties. Also, interaction frequency and degree are highly important for analysing trust. It is probable that those that participate in this network will be in cliques because of the necessary trust levels. It was consistently noted in the community that this informal labour sharing practice has deteriorated in recent years. Many noted that it is difficult to trust people to return the work that they give. It was suspected to be an important element in the community because of its low welfare levels. However, this was not the case.

Family

Familial ties are inherent links. The trust measures were expected to be exceptional because of the innately stronger bond (Bandiera and Rasul, 2006). However, during the qualitative study it was found that there were a number of deep rifts between family members. Hence, they may not be the source of insurance that they are widely assumed to be. It was noticed that families are likely to be spatially arranged due to land holdings. This could cause spatial clustering. In turn this may also increase closeness within families. However intra-family links may have low closeness measures because of the spatial distinction between families. Centrality, position, and ego, which are measures of prominence, are most likely to be apparent because of the hierarchical nature of the culture. It can be assumed that there will be spatial clusters characterized by high levels of centrality.

Informal Insurance

This network provides another measure of strength of ties (Fafchamps and Gubert, 2004). However, it was suspected that data quality would be low because of reluctance to release this information. This is significant because money is exceptionally sensitive in this culture. The network is probably ego-centred since the exceptionally wealthy are more likely to lend because of an assumed responsibility. This means that centrality, position and ego should be of substantial importance, especially because those of similar welfare levels may be too proud to borrow from one another. The frequency of this interaction would be key to understanding the level of financial ties and their density. Another point is that since the average welfare level of the community is low compared with those surrounding it, it was thought there could be camaraderie that induces lending. Closeness will most likely be a central factor in the structure since people would assumingly have minimal social distance due to the sensitivity of the relation. This would probably occur regardless of the centralization of the network.

Partners

Like day for day, this is an informal risk insurance network. This is essentially a RCA. As is well known, RCAs require a high level of trust amongst their participants (Fafchamps and Gubert, 2004). Partners, like day for day, is a traditional organization that has been diminishing. It was not clear how much presence it still had in the community. Usually partners is predominantly composed of women since males view it as belittling due to the dependence that it necessitates. Also, it is not unique to one social class. Since partners has no hierarchical element (except for the person who controls the purse and who is changed after every round) ego, position and centrality are of minimal significance. The most important characteristics of this network are density, closeness and frequency.

The density of the network will probably be the lowest amongst all of the networks. This will show that the activity has little significance to the network at large. However, the location and characteristics of participants could indicate that particular farmers are more likely to participate. Moreover, it could indicate that there are sections of the community that are more socially resilient than others and are possibly exclusive. This could be central in identifying any fractures (or subgraphs). This is important because social division can impede the efficiency of information flows, particularly due to the exceptional level of trust and collective effort that is needed. With regards to closeness it is assumed that those who participate will have short social distances due to actors' intimate knowledge of one another. Frequency is expected to be high because those that have strong ties will most likely interact frequently.

Tool Sharing

Tool sharing is common but there are those who are protective about their tools. It is essentially another measure of trust. This network is expected to be large because the activity is frequent, since when farmers work together they borrow one another's tools. Centrality, ego and position are unlikely to have much significance due to the low variation in tool costs. There are some tools that have exceptional cost such as pesticide blowers and long range irrigators, but very few farmers own these tools and they are seldom lent due to their high value. The characteristics that are of particular interest are frequency, density, closeness and direction. Frequency will show whether or not it is significant for actors to have consistent interaction in order to lend tools, which shows the level of trust necessary for the exchange. Moreover, closeness provides the measure of social distance (geodesic distance) within the graph, thus indicating whether actors have a long range of interaction between one another. Actors would have particularly low closeness measures since what is being shared does not carry substantial value. However, the direction of the sharing should indicate dependence. Density is another characteristic that will be significant because it determines whether actors can trust each other enough to engage in an activity that requires minimal trust. If the network is rather sparse, it shows a general lack of trust where people cannot be trusted to share inexpensive tools.

Network Specific Questions:

Sweet Potato Advice

There is only one question that is particular to this section which is a rating of the advice quality. This will help to identify the advice quality of the farmers and clarify the structural implications of this.

Planting Material Sharing

Directionality of sharing is captured by collecting information on the sharing relationship. The crops shared were also collected. It could be quite interesting to understand what crops were shared because of the significance of the particular value of certain crops. For example, peas and pumpkin seed may be more readily shared than peanut cuttings due to the value of the latter in the community. This gives an indication of the market and welfare relationship of the links. However, a crucial crop that could not be captured was marijuana. This is the dominant income for full-time farmers in the area but the exceptional sensitivity of this information prevented its collection. Understanding the sharing of this crop would truly give an idea of the strength of ties amongst farmers, given the secrecy and protection of its cultivation.

Market Sharing

The quality of the information that was exchanged provides insight into the link between market information and the innovation (Spielman et al., 2008). Moreover, it can determine where there is a correlation between market leaders and farmer teachers. This is significant in understanding the complexity of the link between market and information sharing, and knowledge levels. Since market was most commonly noted as the key determinant of adoption it is important to show its relevance and the level of sophistication of the relationship.

Hired Labour

Analogous to market sharing, the only unique variable for this network is the quality of service. The same scale rating is used. Something special here is that the hiring of labour is also a determinant of welfare level. Those farmers that are hired frequently in the community may have a lower welfare level but a higher knowledge level, due to their experience with numerous planters. Hired labour in general is viewed as a low-end job and farmers aspire to stop work as a field worker. For example, one farmer with a higher welfare level insisted that he does not do hired labour even though I had information to the contrary. Thus, there is a bit of embarrassment in doing such work if you are moving from one welfare position to another. In the hierarchical culture, where there is a strong drive to

becoming a ‘big man’, ‘head man’ or ‘manager’, farm labour positions are deemed as ‘dirty work’. Understanding the adoption, knowledge and welfare levels of these people in regards to their labouring frequency would give an idea of this social stratification.

Informal Insurance

The only question here is the direction of money sharing. This simply identifies interaction direction, hence the in- and out-degrees specific to informal insurance. This will reveal whether or not there is centrality with respect to money sharing.

Tool Sharing

Again there is only one network specific question. It asks how long the farmer has been good enough friends with the link to borrow or lend a machete or hoe. This simply qualifies what is being shared and the number of sharing years. This is a measure of tie strength. Hence, it will indicate how close the actors must be in order to share tools.

3.4 Qualitative Study

In order to identify the networks and to have a more subtle understanding of issues I developed numerous in-depth interviews and a focus group. The purpose of the qualitative study was to aid the construction of the main survey. It was not meant to act as a standalone analysis, but to provide information that would increase the survey's precision and effectiveness. There was a particular emphasis on identifying social characteristics and networks. Twenty-three in-depth interviews[23] were performed based on the following characterizations: Elderly; Early Adopters; Late Adopters; Socially Popular; Non-Adopters; Farmers Exporting Exclusively; Minimal Pest Damage; Long Time Labour Sharing Participants; Elderly RCA Members; Sweet Potato Traders; Heads of Farmer Groups; Agricultural Trainers. There were a few other characterizations[24] that were sought but the respondents either did not consent or requested not to continue the interview. These characterizations were chosen strategically in order to extract specific information for understanding learning, adoption and social effects. The focus group[25] was performed on an ASSP group meeting. An officer involved in the ASSP initiative was present during the focus group. The reasons for the chosen characterizations are listed below as well as the general questions that were used for the in-depth interviews. The focus group questions are also listed.

For the in-depth interviews the principal goal is to understand the informal social group characteristics for instrumentation, particularly with respect to farming technology and information dissemination (with respect to sweet potato and IPM), and market access. In

[23] Refer to Appendix 5 for the in-depth interview questions.
[24] Women; Young Farmers; Advice Connection Outliers; and Short Term Labour Sharing Participants.
[25] Refer to Appendix 5 for the focus groups questions.

addition, the general purpose is to gain a thorough understanding of the social features that would influence technology diffusion.

The interviews were conducted during December 2007 and January 2008. I chose the respondents based on the characteristics listed above as well as their farming involvement and history. It was sought to choose those farmers that were more involved in the farming community in order to retrieve more substantive social effects answers. Moreover, persons that were more comfortable with me were targeted as they would be more open to releasing information. There was not a particular order for the interviews, it was simply based on the interviewees' convenience. The interviews were mostly conducted in private except for those where it was not possible. In general the respondents were forthcoming with information. Although, some had difficulty answering questions regarding perceptions of the community since they felt that they could not speak for others' experiences. Some respondents were also apprehensive towards questions on money-lending as this information is very sensitive for some.

A number of insights were drawn from this study. I will provide some reflections on how it influenced instrument development and model construction.

Instrument Development

Having a more subjective understanding of social effects gives a more complete understanding of the community's social characteristics. Furthermore, it enabled me to develop more fitting instruments. There were a number of significant instrument designs based on the qualitative results. One important question that was included was farmers' preference for group or individual government support. This was based on the response from numerous farmers that they distrust collective action.

The informal insurance network was also added to the network list as farmers noted that money lending is common. Unfortunately, it was found that there was great reluctance to releasing this information. The creation of a tool sharing network list was also dependent on the farmers indicating that they often share tools. This provided another social entity where farmers could be disseminating information. Other instrumentation regarding network formation and information sharing was added as farming knowledge was found to be a strong determinant of social interactions. This particularly regards the 'Technique Use' section in the main survey wherein there is detailed information on how farmers receive innovation information.

The instruments' focus was placed on informal networks because the interviewees indicated that no formal or community recognized networks act as information sources. This meant that I was able to narrow my focus on this particular network type. Also, more detailed questions were added such as reciprocity, and network direction as they were determined to be significant by the qualitative study.

Model Construction

Model specification was also influenced by the qualitative work. The IV-2SLS model in chapter 4 was influenced by the comments regarding bias in RADA support. This led to the use of an IV model to control for potential endogeneity from RADA contact and suspected omitted variables. In addition the choice of variables, such as those for market, the number of primary school children in one's household and previous labour sharing membership was based on interview responses.

In Chapter 6 the use of the preference for information over market farm support variable was included due to farmers noting the predominance of markets in influencing interactions, learning and adoption. It was uncertain if markets were particularly significant but the interviews showed a virtual consensus of markets being the most significant influence in the innovation process. Another variable is the preference of individual over group oriented government support. Many responded that self-reliance is preferred over community organization, which indicated the potential significance that this characteristic would have in network development. A variable that captures this behaviour would give an indication of potential clustering in the network estimations. This is significant to determining division in the community.

These examples provide an idea of the significance of the qualitative work to the model specification and identification.

3.5 Conclusion

Network data collection is plagued by many issues. The complexity of network effects necessitates that the instrument be equally complex and because of this, its intentions must be properly explained. This chapter illustrated what has to be accounted for in network instruments to correct for identification issues. Issues such as the 'reflection problem' and ensuring that a proper boundary is established are central to the study's credibility. There are other studies such as Fafchamps and Gubert (2007), and Bandiera and Rasul (2006), which are excellent, that were not able to correct for these critical data issues. The reason for this is that it often is too tedious to attempt to correct for these problems as there is a risk in causing high attrition. de Weerdt (2002) is a truly unique study since it was able to correct for seemingly all network data concerns without any attrition. This is the goal. However, it is difficult and that is why de Weerdt (2002) is unique. It is actually best for there to be fewer but higher quality studies. Thus, although there is a burgeoning literature on analytical methods, what needs more focus is data collection. Data collection methods for network studies is still in its infancy and this is why substantial effort was spent to try to correct for these issues. There needs to be more discussion on data issues and that is why we took the time to thoroughly explain the intentions of the instrument for analysing network effects. The addition of high quality datasets is significant because it enables more sophisticated analysis. The effort by de Weerdt is evidence of this, as the dataset has been used for numerous publications, particularly Van den Broeck and Dercon (2011).

The following chapter on adoption begins the empirical analysis and will investigate what influenced adoption outside of networks.

CHAPTER 4

Adoption

4. Introduction

In this chapter we analyse adoption without taking account of networks. The purpose is to provide an understanding of pheromone trap adoption and extension's respective relationship. This is done to provide comparison with the network estimation as to clearly differentiate individual and network influences, as well as to identify extension's significance with regards to adoption and networks. The estimation employs models correcting for endogeneity. A few themes are used to focus the analysis. We begin the chapter with a review of the data and descriptive statistics.

4.1 Descriptive[26] Statistics[27]

This chapter employs panel data as it is significant to account for the temporal influence. The dependent is the pheromone trap adoption since this is the innovation within IPM with the most viable panel responses. The estimation covers the years 2003 through 2008 for 64 respondents.

As seen in Table 2, the adoption rates over the period of interest are moderate. The rate is low at 22% beginning in 2003, then climbs to its highest around 53% in 2005 and finally declines thereafter. There was a particular jump in 2005 (22% from previous year) because of the high sweet potato price (this was caused by a hurricane's destruction of crops in competing countries). However it is uncertain if the market price is the direct reason for the increase in planting as well as adoption. It was noted by a government source that the rival exporting countries in this year had their crops destroyed by a hurricane. Although this was the case, it is unsure if the farmers used traps to ensure that they had a higher percentage of export quality crops[28]. After this year there was a decline in adoption in the overall sample. This is probably related to the decline in planting after the spike in prices, although adoption with respect to the number of plantings shows an increase. Adoption actually increased steadily, indicating that the innovation was well received.

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[26] The various descriptions for this chapter along with their corresponding questions in the questionnaires are give in Table 16A in the Appendix 4.

[27] The data source is the author's own data collection that has been detailed in Chapter 3. All statistics in thesis are based on this data.

[28] The source indicated that it was uncommon for farmers to seek out market information from the government (although the farmers stated that they were rarely given market support even when it was requested).

Table 1: Adoption Descriptive Statistics

Years	Farmers Adopting	# of Times Trap is Adopted	Total # of Years of Adoption Experience	# of Years of Adoption Experience for *those adopting prior to introduction*	T # of Years of Adoption Experience for those adopting after introduction
Pre-2003	9	NA	NA	NA	NA
2003	14	18	41	35	6
2004	20	24	64	47	17
2005	34	41	98	56	42
2006	30	34	136	65	71
2007	27	31	131	52	79
2008	27	28	103	58	45

Notes: 64 Observations. Total # of Adopters over 2003 to 2008 = 44, thus an adoption rate of 0.69

Table 2: Adoption Rates

Years	Adoption Rate per Year[29]	Adoption Planting Rate[30]	Adoption Frequency Rate[31]	Adoption Years Rate[32]
2003	0.21875	0.333333	0.428571	0.34163
2004	0.3125	0.408163	0.489796	0.3125
2005	0.53125	0.557377	0.672131	0.346939
2006	0.46875	0.566038	0.641509	0.220588
2007	0.421875	0.627907	0.72093	0.206107
2008	0.421875	0.964286	1	0.262136

Notes: 64 Observations

The statistics in Table 1 show that there was only a minimal number of people that adopted the technology before its formal introduction to the community. Before 2003 there was a pilot program from the government as well as an independent sweet potato cooperative that was providing the innovation. The first reported importation of the

[29] The number of farmers adopting divided by the number of farmers
[30] The number of farmers adopting divided by the number of sweet potato crops for that year
[31] The number of times adopted divided by the number of sweet potato crops for that year
[32] The number of farmers adopting divided by the number of years of experience in the innovation

technology was in 1998, which was through the Christiana Sweet Potato Cooperative (CSPC). An interesting point is that the adoption rate declines instead of stabilizing or increasing. In general it seems that the community is inconclusive about the effectiveness of the pheromone traps. For example, the most respected farmer and informal teacher in the community stopped using the traps because he believed that they were increasing pest damage, thus he eliminated it from his IPM regime[33]. What is important to note is that many seem to use the trap simply because it is a popular technique and they may feel embarrassed or less savvy if they do not adopt it. This indicates that they do it since it is *en vogue*.

Another interesting statistic from Table 1 is that the number of people adopting with respect to the number of plantings steadily increased, meaning that there is a higher concentration of adopters out of those that are planting. This indicates that although the number of people adopting in the community is smaller, that those planting are adopting the technique. This is a promising indicator as it means that the technology is becoming entrenched in the community's planting techniques. Furthermore, as planting expands technology adoption should correspondingly expand. This could particularly be the case in the future since those that are planting now would act as teachers for new planters and would exemplify that almost all the people currently planting have adopted. In this situation mimicking and/or observational learning would be substantial. Most noted in the in-depth interviews was that field neighbours observe each others' planting techniques. This is of greater significance than the overall adoption rate because it shows that the adoption rate of those planting is converging towards unity as is shown by the final adoption year.

One variable that indicates detrimental results is the proportion of adoption years with respect to the adopted. This shows a decrease over time which indicates that there is less experience in the community with regards to the adoption rate. This is of concern because in order for the technology to be taught effectively as much experience as possible is wanted amongst the present adopters, for these are the people whom prospective adopters would be most inclined to contact since they are in the planting process. It could be detrimental to learning if it is found that experience is significant to the innovation's social learning. However, it is also indicative that the most experienced are leaving either the crop or the innovation. Both circumstances are disturbing since these are exactly the people needed to maintain adoption in the community. Moreover, if these people are exiting then there could be numerous repercussions that would affect the production, trading and ultimately the innovation process.

However, if we look at the other figures in Table 1 that differentiate the experience of those who adopted before the adoption period and those who adopted after, those who adopted before have a greater number of years in all the adoption years except one. This is a good indicator because it shows that those who hold the characteristics (of an innovator) for early adoption are present for aiding new adopters.

[33] Told during in-depth interview

Overall it seems that the technology introduction was moderately successful and the next step is to understand what is related to this innovation's popularity. Before discussing the estimations the procedures for correcting endogeneity are reviewed.

4.2 Estimation

The analysis is divided into five sections: Extension; Market; Welfare; Risk; and Innovator. These were chosen since they were determined to be the most significant issues to adoption (Feder, Just and Zilberman, 1985). Instrumental Variable (IV) estimations will be presented for each respective estimation theme. Before the discussion of estimations, endogeneity is reviewed.

4.2.1 Endogeneity

Endogeneity simply concerns the correlation of explanatory variables with the errors. Moreover, it creates bias in the estimation's intercept. This is primarily caused by omitted variable bias and is normally corrected by instrumental variable estimation. Endogeneity is the most suspected issue in adoption analysis as it is often assumed that there are omitted variables, correlated with the dependent and the error term (Asfaw, 2010). For example, in this sample, political affiliation could have been significant to adoption since it was often reported that extension assistance was based on political party membership. However, due to the question's sensitivity, sample members would probably not have answered, or would have lied. Due to extension services in the area having insufficient resources it is thought that measures are taken to quickly identify participants in extension activities, whether it is political affiliation, space, wealth, land owned, or any other factor.

4.2.2 Empirical Model

An Instrumental Variable Two Stage Least Squares (IV-2SLS) model is used to control for endogeneity caused by suspected omitted variable bias. Rather than using an array of estimations the analysis will use a few models for each respective estimation type. The reason for this is that there were not particularly informative results from the large range of estimations that I used, so I chose to use a few models as reference. However, I support this estimation by reflecting on this array of estimations, with an emphasis on the variable choice, in order to show why I chose these particular variables and model specifications. The purpose of this estimation was not only to highlight the adoption themes listed above but particularly to understand the influence of extension outside social influence. In the chapter on social networks the purpose will be to highlight the social channels used for exchanging information and influencing behaviour.

The IV-2SLS model was used to correct for endogeneity. RADA contact regarding sweet potato is assumed to be the endogenous regressor as it is highly likely that there is correlation with the error term. Moreover, the variable is strongly correlated with the dependent. The instrument that was chosen is an innovation's age being insignificant to adoption. This variable measures a person's propensity to seek an innovation as it captures those people that are highly likely to innovate and seek out the most effective technology.

It is suitable as an instrument because it accounts for innovation directly. Those that are more inclined to innovate are strongly related to RADA because of this interest and the exceptional support they receive. The last aspect of the model is that bootstrapping was used to control for the standard errors, since the error terms are correlated between the instrument estimation and the outcome equation. Thus the standard two stage procedure presented in Figure 5 was performed for the IV estimation.

Figure 5: Adoption IV-2SLS Panel Estimation

(5) Selection Equation: $$x_{k_t} = \boldsymbol{x}_t\boldsymbol{\delta} + z_t\theta + \boldsymbol{r}_t$$

(6) Outcome Equation: $$y_t = \boldsymbol{x}_t\boldsymbol{\beta} + x_{k_t}\tau + \boldsymbol{u}_t$$

y = dependent: pheromone trap adoption

x = exogenous variables vector

u = outcome error term vector

z = instrument: innovation age is insignificant to adoption

r = selection equation error term vector

$_t$ = temporal term

$_k$ = endogeneity term: RADA sweet potato advice contact

4.2.3 Controls

I begin with a discussion on the choice of controls. The controls for the estimation are: age; literacy; household size; acres; export buyers known; hospital fees; primary school children; and the number of years planting sweet potato. There are a number of different characteristics that I sought to capture through the controls to ensure an appropriate balance to the estimation. The basic characteristics that were essential to be accounted for are age, literacy, wealth, market access, and experience. Age is particularly significant as extension may be related to a certain age group. It is often noted in the literature (also by RADA) that younger farmers are savvier and more open to innovation because they are more dynamic, but there may be other reasons for why age would be of significance (Adesina and Baidu-Forson, 1995). For example, in this research area there are few young farmers as most young people plant marijuana. Also many farmers noted in the qualitative interviews that older farmers often do not acknowledge modern innovations, which supports this position.

Age was not significant in any of the preliminary estimations; however it needs to be included as it is significant in the literature and to the ministry (Adesina and Baidu-Forson, 1995).

Literacy was thought to be central and to have a strong correlation with extension since the literate would be more comfortable in an educated environment (Alene and Manyong, 2007; Croppenstedt, Demeke and Meschi, 2003). It was positive and significant in the preliminary estimations. The significance of this variable is surprising since from my interactions some of the most capable farmers were illiterate. However, from my experience it seems that it is insignificant as long as trainers can communicate in an effective manner, such as here where the officers use the informal dialect *patois*.

Farmers who are less educated are usually more reliant on farming for their livelihood. Jamaicans generally enter into farming as a last resort since there is substantial risk (market instability, theft, hurricanes, etc.). Literacy did not have a particular effect on extension contact, but its inclusion as a control is key because it is widely seen in the literature, as well as by the country's ministry, as significant to adoption and extension interaction (Alene and Manyong, 2007). The only education variables are literacy and secondary school. Literacy is the only one of significance and it was positive. Although the affect on adoption was not exceptionally strong as it is highly likely that a community with near full literacy would have substantially higher adoption rates than those with low literacy such as here (49%). Thus this is another reason for its inclusion.

Wealth is another fundamental variable that is likely correlated with extension. The wealthy are likely to have more extension interactions since they command more respect (Feder and Umali, 1993). The following variables represent welfare in the estimation: Household size; acres owned; hospital fees; and children in primary school.

Household size was significant and positive in the preliminary estimations which indicates that larger households are more likely to adopt than smaller households. In this situation innovation adoption is used as a welfare maximization strategy, hence the farmers are risk takers. In this scenario small farmers are being aggressive in maximizing their welfare status. The qualitative work supports this finding as many farmers noted that they adopted the most effective planting techniques regardless.

Medical costs that cause unplanned stress on the household economy were found to be notably representative of wealth. Hospital fees was significant, positive and particularly robust. As it is only those that have significant disposable income that can support the ill, these people probably have significant wealth.

Acres shares a similar result with the age variable as it was consistently insignificant in the preliminary estimations. However it had to be included because of its significance in the literature.

There are a couple other welfare variables that gave some interesting results. For example, the number of children in primary school was significant and negative. This could illustrate that the welfare levels of those households with more children reduce adoption probability because of risk aversion caused by their low welfare status. This variable was kept as a control since it was shown to reduce the significance of the extension contact

variable. Children are often the main financial strain on a household thus it would be indicative of how a farmer responds to this stress.

Market access is important as it is the most significant influence on adoption, based on the qualitative study. It must have a strong influence on extension participation in addition to other variables. This will show whether or not markets are tied to extension contact, which is significant in understanding if markets are a driver for reaching out to trainers. This is an influence that needs to be accounted for as extension could essentially be capturing market effects.

The strongest variable in the preliminary estimations was export market buyers known. This provided ample support for the literature's prevailing adoption influence, which is market (Feder and Umali, 1993). Since the primary reason for the adoption of this technology is to improve crop quality, so as to expand in the more lucrative export market, this confirmed the results of the qualitative study wherein farmers universally responded that the market is the most important reason for adoption. What is of particular significance is that the export market is the primary market target. This indicates that farmers are willing to take the necessary measures to improve crop quality so that they can achieve a higher price.

Crop experience would also be particularly relevant to extension contact (Adesina and Zinnah, 1993). Intuitively, it is those who have invested in the crop repeatedly that would be keener on learning about it. Also, older farmers usually prefer traditional techniques in contrast to more open minded young farmers. The estimations showed that sweet potato planting experience is strongly correlated to sweet potato extension contact. However, crop experience was insignificant to adoption. This counters the prevailing thought in the literature that experience usually determines investment (Adesina and Zinnah, 1993). Although, it can be indirectly relevant to investment as farmers noted in the qualitative interviews that crop experience is one of the main variables that influences market access. Essentially, those that have more market experience with a crop will have more market access and consequently more incentive to adopt.

4.2.4 Extension

The variables representing extension are RADA sweet potato pest advice contact, visiting the RADA office, and preferring a friend’s innovation advice over RADA’s. The dominant variable of these is RADA advice contact. Moreover, it is the treatment variable. We will begin with the defence of this variable and continue in the order given.

RADA pest advice contact was consistently very significant in the preliminary estimations. This is why it was chosen as the treatment. An intention of the study is to determine the influence of extension on adoption. In order to ensure that this was the most suitable variable, a couple other extension variables were estimated to ascertain if any other variables were more robust. A variable that was of particular interest as a treatment was one’s preferred sweet potato information advice source, which was also consistently positive and strongly significant. This variable captured whether a farmer preferred RADA or another farmer’s advice. The advantage of this variable is that it forces the farmer to

clearly define the most influential training source rather than noting advice contact. However, it does not directly regard pest issues and it only accounts for positive interaction, hence the variable is not as fitting. In addition, this variable was not preferred because it accounted for social effects when the only concern was extension influence for the treatment.

The next variable regards those that have visited a RADA office. It is believed that those who make an effort to travel to an office would have closer ties to extension because they are making an exceptional effort to engage with them, thus they would be more inclined to adopt because of the value given to learning. However, the results indicated that the opposite effect occurs. This is likely due to a number of people who discredited RADA after they visited their offices after hurricanes in search of material assistance, but were refused. The relationship is significant because it captures negative forces on extension, which aids in ensuring a robust extension estimate.

The innovation advice variable was particularly interesting. It simply asks if RADA or a friend is preferred for innovation advice. It was determined that it would be best to estimate preference for a friend's innovation advice rather than RADA's as that was essentially captured by the RADA contact variable. Both fellow farmers and RADA were accessed for advice, but for different reasons. The former was contacted due to convenience and the latter due to expertise, based on the qualitative interviews. Also I was told by farmers that both sources are viewed favourably even though the latter is viewed as having political and friendship bias. The estimates were positive, which seemed peculiar due to the RADA training results. Although this does not capture the relationship to RADA, it makes the RADA contact estimate more robust by controlling for potential social connections. It was stated that the purpose of this chapter was to account for adoption influence outside of social effects; but the relevance, strength and significance of this coefficient forced its inclusion as a control for RADA contact.

4.2.4.1 Final Estimation

IV-2SLS

There are a number of interesting results presented in Table 3 (the remaining IV-2SLS estimations are given in Table 3). It is important to understand the significance and influence of extension as it accounts for the influence of the training source (Agarwal, 1983). This is central to understanding adoption as it is the primary information source for farmers outside a group setting. Moreover, because this variable accounts for individual interaction with the training source it represents non-group oriented pressure on adoption. This contrasts with the ASSP and RADA group trainings, and shows the significance of personally oriented training. The first estimation which only includes the controls and the extension variables shows the RADA pest advice contact variable to be very significant and to have a substantial coefficient. This shows how important extension is to the adoption process. This is even with farmers stating in the interviews that RADA has poor availability.

Table3: IV-2SLS Panel Adoption Estimations[34]

Variables	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Age	-.003(.011)	-.017(.010)	-.012(.010)	-.010(.012)	-.013(.013)	-.019(.016)
Literate	.409(.266)	.492(.225)**	.388(.252)	.467(.257)*	.256(.266)	.276(.260)
Household Size	.069(.043)	.082(.046)*	.068(.052)	.071(.051)	.083(.060)	.096(.052)*
Acres	.021(.011)*	.003(.030)	.003(.036)	.009(.033)	.011(.038)	.008(.026)
Export Buyers Known	.256(.067)***	.207(.075)***	.200(.067)***	.224(.083)***	.192(.079)**	.189(.069)***
Hospital Fees	.197(.179)	.409(.220)*	.429(.211)**	.382(.226)*	.331(.234)	.345(.215)
Primary School Children	-.199(.136)	-.375(.201)*	-.363(.222)	-.292(.198)	-.235(.224)	-.278(.201)
# Years Planting SWP	.029(.019)	.013(.016)	.022(.020)	.021(.019)	.019(.021)	.019(.021)
RADA SWP Contact IV *Innov Age*	-	.458(.144)***	.421(.160)***	.359(.147)**	.294(.143)**	.314(.169)*
Visit RADA Office	-	-.411(.240)*	-.311(.262)	-.230(.241)	-.295(.218)	-.267(.231)
Friend Innov Advice	-	.800(.305)***	.695(.413)*	.655(.360)*	.732(.439)*	.892(.422)**
Poor Market Access	-	-	-.547(.330)*	-.568(.342)*	-.458(.352)	-.492(.403)
RADA Market Advice	-	-	-.015(.371)	-.076(.284)	-.344(.309)	.048(.316)
Microwave	-	-	-	-.509(.272)*	-.344(.309)	-.429(.403)
Labour Sharing Past	-	-	-	-	.359(.349)	.372(.298)
Nursery Adoption	-	-	-	-	.081(.361)	.092(.318)
Information or Market Support	-	-	-	-	-.631(.233)***	-.561(.289)*
Pest Scouting	-	-	-	-	-	-.171(.310)
Pest Barrier	-	-	-	-	-	.349(.461)
Adopt to Reduce	-	-	-	-	-	.309(.244)
Observations	384	384	384	384	384	384

Notes: * significant 10%, ** significant 5%, *** significant 1%

[34] Linear probability estimations are in Table 3A in Appendix 1

In model 2 all the variables are significant although it is RADA advice contact and preference for a friend's innovation advice that are very significant. It is particularly interesting how the coefficient size of the latter variable is the largest, almost twice as large as the RADA contact variable. The inclusion of this variable was meant to give an understanding of the relevance of the advice of other farmers. This is not particularly capturing a network effect but simply determining whether a person would prefer advice on innovations from farmer friends rather than RADA. This gives an insight into their affinity for an informal source over a formal training source. The common explanation for why farmers preferred asking a farmer friend rather than RADA for innovation advice is simply convenience. It is difficult to get in contact with RADA officers, whereas a friend in the community would be readily accessible and would be able to take the time to discuss it with them. This indicates that informal channels are likely to be significant to the adoption process and have a substantial influence on adoption.

The visit to RADA office variable is negative and only slightly significant, but it illustrates that actively going to the office for advice is related to non-adoption. It was assumed that those who are taking the initiative to seek out advice physically would be more competent because they are displaying a stronger intent for adoption. One possible reason for the result is people becoming disappointed in their visits and consequently minimizing their interaction with RADA, hence causing a lower probability of adoption. Otherwise, it is unsure what this may be capturing.

In model 3 there are a few changes to the extension variables with the introduction of the market variables. The visit RADA office variable becomes insignificant and the preference for innovation advice from a friend becomes only slightly significant. This is due to the relationship between the RADA market advice and friend innovation advice preference variables. It is likely that the responses were similar as people would favour one or the other. The following model shows something interesting which is an interaction between RADA contact and the welfare variable. There is a substantial reduction in the influence of the coefficient as well as its significance, thus supporting the suspicion of the farmers that there is bias towards wealthier farmers.

For model 5 we see the inclusion of the risk-related variables. This shows a further reduction in the influence of the RADA contact attribute. This is particularly due to the nursery adoption and preference for information support variables, as they are both related to extension since they represent a more interested farmer. A person who is adopting to reduce pesticide use would certainly have contact with RADA regarding pesticide reduction since it is the training source. This is the reason for the correlation. However, it causes an increase in significance of preference for friends' innovation advice.

4.2.5 Market

The variables of interest in the final estimation are poor market quality perception and preference for RADA market advice. For the former the meaning is intuitive. The latter variable is included in the final models to account for the farmers' closeness to extension, markets and the community. Those who place preference for finding markets through the extension agency would be more detached from the community, since almost everyone

sources markets through friends. Thus if one is using RADA for market access, it is due to poor network connections. Furthermore, it indicates that the farmer has little market knowledge, in that they do not know how or who to approach in the community to get market information, based on the in-depth interviews. Market perception has a number of components (Cai et al., 2008). When a farmer perceives market quality the primary influence is their welfare status (Cai et al.). This will bias their result because the pressure of a high risk welfare position will lead to a negative market view. Another point is that they may be disappointed in their own crop failure and blame the market for not accepting low quality crops. However, what is important is not necessarily why the respondent answered in the way that they did, but that their perception is defined as such. Whether their evaluation of the market is defined by cowardice, shame or overconfidence. it is a reflection of their satisfaction of the market and hence this influences how they invest in the crop for that market.

What is interesting regarding market quality is that those who have noted very good market access are strongly insignificant to the adoption process. This may be because those who note very good market access are probably doing so because they have numerous local market contacts. Furthermore, since local market is insignificant to the adoption process it follows that those who have numerous local connections would be insignificant to adoption as well. This is why this variable was not included, as it did not bring particularly significant information to the results. All it did was confirm the insignificance of the local market estimation; but what is important is understanding the influence of the export market. The market perception variable of most interest was poor market quality, because it could provide contrast with the export market variable if it was negatively correlated. This provides a more complete understanding of market effects by showing the push and pull factor that it has on innovation behaviour. This result supports its inclusion in the final estimation models as the results were robust throughout the preliminary estimations.

4.2.5.1 Final Estimation

IV-2SLS

There are three market variables, and one of them is amongst the controls. The latter, the number of export traders known, is the strongest variable in the entire estimation. The other variables are poor market access and RADA market advice. Having an understanding of the influence of markets is critical because markets often drive innovation (Asfaw et al., 2011). In this situation the particular concern is the export market because the innovation is being promoted to increase export market access. It is assumed that access to this market will strongly determine adoption. The variable is the only estimate that is strongly significant for all models. The estimate is robust and illustrates that export market access is central to spurring adoption as those who have more export trading connections are more competent. It is only in the fifth model that there is a change in significance and this is due to the inclusion of the nursery variable as it is related to curiosity and innovativeness.

There are a couple interesting notes with regards to the other market variables even though there are only two significant estimates, Poor market access shows, albeit slightly, a large coefficient that is negatively correlated with adoption. This provides support for the position that those with poor market access would not be adopters as they would probably have poor quality, thus showing the connection between innovation, markets and crop quality. This result coincides with the qualitative study as many noted that crop quality is central to market access. However, the estimate is not particularly robust.

RADA market advice is insignificant for all the estimations. This indicates that RADA is insignificant in providing market support. What is important about this variable is that it accounts for any bias for extension based on market assistance. It results in no change for the RADA pest advice variable, but substantial change in the remaining extension variables.

An interesting note is that the sweet potato planting experience variable is insignificant. Numerous farmers in the qualitative study noted the significance of experience for market access. This is due to more experienced farmers having more time to build trust with traders and to build higher quality market networks. However it did not display any significant correlation with the market variables.

4.2.6 Welfare

Due to the breadth of options, it took the longest time to choose the most appropriate variables for welfare (Graff, Roland-Holst and Zilberman, 2006). There are various views on the significance of welfare in technology adoption (Feder and Umali, 1993). A RADA officer I interviewed noted that it is a primary influence as those that are better off are usually more engaged with extension because of social parity, meaning there is no class issue causing anxiety. These people are expected to be first adopters because they are more engaged with the training source and since they are less risk averse. However, from my interactions with the community it is possible that those with a lower welfare status are more likely to adopt and are less risk averse because their desire to improve their welfare position reduces their risk aversion. There are myriad welfare variables, so many estimation configurations were made to assess welfare significance. I grouped welfare into five sections: House characteristics; Durables; Financial debts; Lump sum costs; and Crop significance.

House Characteristics

The quality of one's home is usually a strong indicator of wealth since that is the primary asset that people normally invest in (Grosh and Glewwe, 2000). The following results were found in the preliminary estimations. A variety of room types and characteristics were taken into consideration. Zinc roof and the number of rooms were two of the significant variables, which were both positive. Living room, which was the other significant variable, caused some interesting results. This was initially assumed to be insignificant, but it was often significant in the preliminary estimations. The reasoning seems to be that those people who are able to add a leisure room are in a significant

welfare class. Moreover, it causes a negative relationship with adoption. These variables were expected to be included in the final estimation but when the IV estimations were performed they had no influence on the estimation.

There are other variables that are surprisingly insignificant such as having an outdoor kitchen or not. An outdoor kitchen is usually a telling sign of poverty because the majority of people have indoor kitchens. In addition, the number of bedrooms was unexpectedly insignificant. This was thought to be a definite indicator of wealth with regards to household characteristics.

The house characteristics were insignificant, thus they are not good indicators of welfare, particularly in the IV estimations.

Durables

The only variable showing any significance is the microwave. This result was also negative, which indicates that wealth decreases adoption probability. One of our suspicions is that a high welfare position discourages adoption because farming is a profession of last resort. This means that the poor would be more inclined to adopt because farming is more significant to their welfare. The common argument regarding risk aversion and wealth would not apply as the significance of the livelihood to the farmer overrides it.

Financial Debts

Overdue irrigation bills were thought to be the most significant variable of the financial debts. Most farmers find it difficult to pay their irrigation costs on time due to high cost and a lack of enforcement. It is only people of a high welfare level that pay their bills on time. Since its estimate was positive, it possibly confirms the theory that poorer people are adopting in order to escape their welfare position. This is a highly significant finding if this is the true driver because it shows that the population is proactive and is willing to exit their 'comfort zone' in order to achieve a higher position. The other debt variables were unlikely to be significant since there are few farmers that have engaged in the formal credit market and many people probably denied farm store credit, due to fear of reprisal. However, when irrigation debt was estimated using IV it was not influential, hence it was excluded.

Lump Sum Costs

These regard funerals/weddings that cause unplanned stress on the household economy. Such events can severely restrain the farmer's budget and cause them to become risk averse (Foster and Rosenzweig, 1996). However, it could also spur innovation since they would want to improve their financial position. The funeral or wedding costs variable was insignificant. It is essentially premised on capturing people with wealth as those sought

out for expensive occasions would have substantial resources. Due to its insignificance it was excluded

Crop Significance

All of the farmers have mixed crops, but there are those crops that are of greater significance than others. The three most significant crops for the area are sweet potato, peanut and pumpkin. The purpose here is to understand whether the adoption of peanut and pumpkin influence sweet potato planting. It is important to understand if there are pressures placed on sweet potato from other competing crops. None of them are significant, so auxiliary pressures from other crops are nonexistent.

4.2.6.1 Final Estimation

IV-2SLS

There are a few variables that account for wealth. The one that is denoted as the wealth variable is microwave ownership, and the others are acres owned and hospital fees from the controls. The first two are not particularly robust as they are only significant in an estimation each and only at the 10% level. The hospital fees variable is shown to be strongly significant in the third model and this is due to the inclusion of the poor market access variable. Its estimate is positive and shows that farmers of a higher welfare level will have a higher likelihood for adoption. As we see in the next estimation, the microwave variable reduces the significance of hospital fees. In addition it is negative, which contradicts the other welfare variables. I am unsure why it is negative, as it was thought to capture a higher welfare level. Thus far the results have been mixed with regards to welfare and adoption. The literature notes frequently that the wealthy adopt because they are not risk averse. This was reiterated by RADA as they suspected that wealthier farmers adopted more and faster.

4.2.7 Risk

It is uncertain how risk averse this sample of farmers is. In the in-depth interviews there were a few farmers that were very risk averse. For example, one farmer, although friends with and farming adjacent to a farmer who adopted the trap in 1998, did not adopt until 2006 when RADA did a demonstration on his farm. There was an almost identical situation where a farmer was next to someone who adopted in 2000, but never adopted himself. These examples indicate that it is more complicated than being *en vogue* and that farmers may be particularly risk averse.

Risk is a difficult variable to capture since it can be represented by myriad variables (Batz, Janssen and Peters, 2003). A few proxy variables are used here: experimentation; labour sharing participation; cuttings nursery; and information or export market support preference. Experimentation is a direct representation of risk, but it was not significant to the adoption process, probably because only a couple people experimented with the

pheromone trap. Day for day represents a trust arrangement. This means that people must take a substantial risk in by trusting labour reciprocation. A result of the qualitative study is that farmers are very sensitive to lack of reciprocation. Since there is substantial mistrust, even in the labour market, it is a substantial risk to engage in this activity. Cuttings nurseries is another variable and shows that the farmer takes exceptional measures to avoid infected cuttings. This was also shown to be significant and positive. Since this technique indicates that the farmer is highly cautious and methodical it was expected to be more significant. Its result could indicate caution in planting.

The last proxy is for those choosing between preference for receiving information or market support for sweet potato. The former represents people who are risk averse and want to ensure that they have sufficient knowledge to properly apply the technology whereas the latter is for those who are solely looking to sell. The results were significant and indicated that those who prefer market support to information support are more likely to adopt.

For the final estimation all the variables presented here were used except trap experimentation and this is because the variable would be almost perfectly correlated with the dependent variable, as a farmer would have to adopt in order to experiment.

4.2.7.1 Final Estimation

IV-2SLS

It was found that only one variable was significant. Preference for information over market support is very significant to adoption, but negatively. This is interesting as it was thought that it would be strongly positive, but it is the opposite. This may be because the farmers preferring information support are non-adopters, thus they want information about the innovation so that they can adopt, but those that have adopted do not need any information as they are aware of the technology. In the final model the significance of the former variable drops sharply with the inclusion of the pest scouting and pest barrier variables. As these are more traditional methods, they would be correlated with those that have not pursued the pheromone trap.

4.2.8 Innovator

Three variables are used to represent innovation: pest scouting; pest barriers; and adopting to reduce pesticide. Two other variables, experimentation and trap innovation, were estimated in the preliminary analysis. The only significant variable was trap innovation, which is positive. It simply includes any farmer who innovated on the use of the trap. In order to be a trap innovator you must adopt, so they are inherently correlated. However, experimentation was insignificant and had no foreseeable influence on the estimation, so it was not included. Pest barriers had only a few adopters so its significance would be unlikely, but this was one of the variables that was expected to indicate innovation since planting a pest barrier is a native innovation that was not included in the IPM program. Also, pest scouting is a technique that will illustrate particular concern for pest invasion, as it takes substantial time to scout a field properly; hence the effort needed for the

innovation is the reason for its inclusion. The last variable, adopt to reduce pesticide, captures farmers that understand the underlying purpose of IPM, which is adopting to reduce pesticide use. This again clearly illustrates an innovative mindset as few had a true understanding of the innovation's purpose, and even fewer would adopt it. Only those who took the time to understand the agro-ecological issues and place value on the innovation's complex significance would adopt for this purpose.

4.2.8.1 Final Estimation

IV-2SLS

None of the innovation variables are shown to be significant, which shows that they are irrelevant to adoption.

4.3 Conclusion

There are a few findings that stand out in this analysis. A particularly outstanding result is the significance of extension contact. This is important as it assures the trainers that their efforts were significant.

The most significant estimate was export market access. The prevailing thought in the literature is that the market is the strongest incentive for adoption and this is certainly shown here. Throughout the estimations the export market access is consistently shown to be a strong influence on adoption. Furthermore, the importance of the market is shown though the negative relationship of having poor market access. As a result the government should enhance their efforts in market support as it is the primary instigator for adoption. That is actually one area that is lacking as the farmers were not particularly aware of the services offered by the government, and those who were often did not receive sufficient market support. If this area can be improved it could substantially increase adoption rates and increase retention. With that said, it would be best if training was enhanced in conjunction with a new market initiative in order to present their relationship clearly to farmers.

Another interesting relationship is the significance of the friend's advice variable and this indicates the potential significance of informal networks. This variable was positive and often strongly significant. This is a relationship that is investigated further in the network chapters.

A final note is that the literacy variable was not as robust as one would have expected. It is widely assumed that literacy is significant to adoption as it reduces several barriers that impede an actor from engaging in the transfer process. This result was seen as an indicator that dedication to farming is probably what compels someone to adopt rather than one's intellectual ability. Also this gave the indication that education and wealth are not particularly relevant, especially as we saw that the welfare variables were not notably influential.

The following chapter concerns the learning analysis that estimates influences on trap knowledge test scores.

CHAPTER 5

Learning

5. Introduction

What is significant about learning is that it measures not only the actors' knowledge level, but also their willingness to engage in a new behaviour. The estimation for learning concerns information sources excluding networks. This means only formal sources and experimentation are learning sources. This restricts learning influence to non-network variables. Two distinct sets of estimations are performed in contrast to the adoption chapter. The reason for this is that one provides a more detailed and intricate estimation whereas the other is parsimonious for network analysis comparison. The initial section will review the descriptive statistics and the remaining sections will regard the estimations.

5.1 Descriptive Statistics[35]

Cross-section data is used instead of panel and the dependent is the score of a pheromone trap knowledge test.

It is notable that nobody made a perfect score on the test, with the highest score being 76.9%, as shown in Table 4. Also, the mean score of the test is quite low at 35.7%. This indicates that the understanding of the technology is low. Moreover, the standard deviation is low showing that most of the people in the community had poor scores. This is a very telling result seeing that training for the technology had begun six years earlier. Although there is a high rate of penetration, the way in which it is implemented must receive extra extension support. This result supports the qualitative result that information diffusion is slow. This finding is important as the sophistication and sensitivity of the technology requires a thorough understanding. Moreover, if it is not applied properly, it can even be harmful.

In Table 5 it is shown that of those that adopted there is not a significant difference with the original mean of the learning rates. Something interesting is that those who did not adopt did learn to a certain extent. The minimum value for the non-adoption learning rate is higher than that for the adoption rate and this shows that even those who have not adopted have a basic understanding. Although it is likely that this value is due to a guess, the maximum value shows a low, albeit, moderate level of learning for a non-adopter. This could be a primary identifier for determining the significance of social learning since even those who have not even invested in the innovation have knowledge of it. Thus there is learning without adoption. Since only 4 out of the 19 non-adopters had contact with trainers regarding pheromone traps, it is likely that social interaction was the main conduit for acquiring knowledge. When investigating network learning it is important to identify

[35] The variable descriptions for this chapter along with their corresponding questions in the questionnaires are give in Table 17A in Appendix 4.

whether actors are learning based not only on their own volition or through informal social pressures, but also on the interaction of non-learning and learning network sources,

Table 4: Descriptive Statistics - Trap Test Scores of Respective Estimation Variables

Variables (All binary except first, yes=1)	Mean	Std. Dev.	Minimum	Maximum	T-Test[36]
Trap Test Score	.357	.144	0	.769	-
Literate	.357(.358)	.147(.143)	.076(0)	.692(.769)	.01
Primary School	.345(.367)	.098(.174)	.076	.615	.60
Mountainside Primary School	.289(.389)	.112(.147)	.076(0)	.692(.769)	2.69
Secondary School	.352(.362)	.174(.114)	0	.769	.29
Export Market	.396(.304)	.145(.126)	.153(0)	.769(.615)	-2.63
RADA Market Advice	.337(.364)	.098(.156)	.230(0)	.538(.769)	.60
Primary Crop Sweet Potato	.440(.330)	.139(.136)	.230(0)	.769(.692)	-2.76
RADA Sweet Potato Contact	.403(.309)	.139(.136)	.230(0)	.769(.615)	-2.70
Non-RADA Training	.425(.331)	.185(.116)	.153(0)	.769(.692)	-2.44
Weevil Most Invasive Pest	.353(.369)	.142(.151)	0(.153)	.692(.769)	.39
Nursery Adoption	.419(.340)	.160(.136)	.230(0)	.769(.692)	-1.82
Innovation Age Insignificant	.377(.315)	.377(.315)	.158(.098)	0(.076)	-1.61
Need RADA to Adopt Innovation	.322(.400)	.322(.400)	.137(.143)	0(.076)	2.22
Trap Innovator	.410(.341)	.166(.134)	.153(0)	.692(.769)	-1.62
Need Information Support	.339(.365)	.047(.169)	.230(0)	.461(.769)	.65
Training Attendance	.395(.320)	.157(.121)	.153(0)	.769(.615)	-2.13
RADA Field Visit	.387(.314)	.131(.154)	.076(0)	.769(.615)	-2.13
Past Day for Day Member	.378(.308)	.156(.099)	0(.076)	.769(.461)	-1.82
Native to Area	.345(.397)	.149(.123)	0(.153)	.769(.615)	1.21
Numerous Relatives	.336(.370)	.173(.126)	0(.153)	.769(.692)	.90
Hospital Fees	.315(.392)	.166(.114)	0(.230)	.769(.692)	1.10
Poor Market Perception	.320(.368)	.150(.142)	.076(0)	.769(.692)	1.10
Satisfactory Market Perception	.348(.359)	.080(.154)	0(.076)	.692(.769)	.23
Very Good Perception	.332(.363)	.176(.137)	.230(0)	.692(.769)	.66

Notes: 64 Observations

[36] This is a comparison of the trap test scores for the null (0) and the effective result (1) for each respective variable

Table 5: Descriptive Statistics - Trap Test Scores of Respective Estimation Variables for Adopters and Non-Adopters

Variables (All binary except first, yes=1)	Mean		Standard Deviation		Minimum Value		Maximum Value		T-Test	
	Adoption	No Adoption	Adoption	No Adoption	Adoption	No Adoption	Adoption	No Adoption	Adoption	No Adoption
Trap Test Score	.375	.315	.163	.072	0	.076	.769	.356	1.54	
Literate	.364(.387)	.334(.304)	.167(.161)	.039(.086)	.076(0)	.254(.076)	.769(.692)	.356(.356)	.47	-.88
Primary School	.354	.329	.117	.041	.076	.230	.615	.356	.73	-.86
Mountainside Primary School	.321(.404)	.300(.323)	.145(.169)	.124(.048)	.076(0)	.076(.230)	.692(.692)	.356(.356)	1.62	.60
Secondary School	.368	.308	.193	.100	0	.076	.769	.356	.31	.33
Export Market Access	.416(.302)	.325(.308)	.158(.148)	.037(.091)	.153(.254)	0(.076)	.769(.356)	.615(.356)	-2.35	-.50
RADA Market Advice	.346(.384)	.321(.313)	.116(.174)	.054(.079)	.153(0)	.230(.076)	.538(.769)	.356(.356)	.64	-.21
Primary Crop SWP	.467(.342)	.356(.304)	.151(.155)	0(.078)	.230(0)	.356(.076)	.356(.692)	.356(.356)	-2.40	-1.29
RADA SWP Contact	.411(.303)	.314(.315)	.157(.154)	.072(.075)	.153(0)	.230(.076)	.769(.615)	.356(.356)	-2.18	.02
Non-RADA Training	.437(.338)	.230(.320)	.184(.139)	.(.071)	.153(.230)	0(.076)	.769(.230)	.692(.356)	-2.03	-
Weevil Most Invasive Pest	.371(.386)	.313(.321)	.029(.046)	.021(.024)	0(.153)	.076(.230)	.692(769)	.356(.356)	.27	.21
Nursery Adoption	.439(.352)	.293(.317)	.162(.159)	.088(.017)	.230(0)	.230(.076)	.769(.692)	.356(.356)	-1.61	.43
Innovation Age Insignificant	.390(.306)	.305(.320)	.167(.127)	.063(.079)	0(.076)	.230(.076)	.769(.461)	.356(.356)	-1.33	.42
Need RADA to Adopt	.330(.428)	.305(.328)	.156(.158)	.088(.045)	0(.076)	.076(.230)	.769(.692)	.356(.356)	2.08	.65
Trap Innovator	.423(.354)	.230(.320)	.328(.295)	0(.284)	.153(0)	.230(.076)	.692(.769)	.230(.356)	-1.31	-
Prefer RADA Technical Advice	.388(.367)	.287(.322)	.181(.152)	.056(.076)	0(.076)	.230(.076)	.769(.692)	.356(.356)	-.43	.86
Need Information Support	.335(.384)	.342(.277)	.065(.176)	.032(.096)	.230(0)	.254(.076)	.461(.769)	.356(.356)	.76	-2.09
Training Attendance	.403(.325)	.314(.315)	.162(.157)	.072(.075)	.153(0)	.230(.076)	.769(.615)	.356(.356)	-1.57	.02
RADA Field Visit	.420(.303)	.295(.336)	.129(.189)	.089(.042)	.230(.076)	0(.230)	.769(.356)	.692(.356)	-2.46	1.24
Past Labour Sharing Member	.401(.298)	.310(.321)	.167(.124)	.086(.052)	0(.076)	.076(.230)	.769(.461)	.356(.356)	-1.87	.32
Native to Area	.361(.427)	.307(.336)	.167(.142)	.082(.026)	0(.153)	.076(.307)	.769(.615)	.356(.356)	1.14	.76
Numerous Relatives	.361(.383)	.277(.337)	.193(.146)	.102(.038)	0(.153)	.076(.230)	.769(.692)	.356(.356)	.42	1.87
Hospital Fees	.352(.394)	.323(.308)	.185(.143)	.054(.088)	0(.230)	.076(.230)	.769(.692)	.356(.356)	.86	-.42
Poor Market Perception	.403	.356	.165	0	.153	.356	.769	.356	-.61	1.47
Satisfactory Market Perception	.307	.312	.243	.059	0	.230	.692	.356	1.20	.14
Very Good Market Perception	.426	.356	.166	0	.230	.356	.230	.230	-1.17	-

Notes: 64 Observations

regardless of their learning rate.

There is also the case where there is adoption without learning, such as shown by the minimum value for adopters. However, the variance for the adopters is higher indicating that there are a substantial number of actors who scored higher, which shows the influence adoption has on learning levels.

Literacy is a major concern for knowledge levels. It is the standard train of thought in the literature that the literate will acquire more knowledge. What is interesting is that the illiterate have almost the same knowledge levels as the literate. The reason for this is that the literate are probably not exceptionally more significant to learning. This is possibly due to the lower significance to the household economy of the literate. Moreover, if it is not a primary income generator then there will be a smaller prospect of there being a long-term investment, hence only the necessary investment will be made for its short term implementation. This is particularly true, since the trap is a sophisticated technology and only a dedicated farmer would take the time to have a thorough understanding of it. What is significant is that the next variables contradict this idea. The level of education shows that those with secondary schooling have higher knowledge levels. It is unsure why this is so, as the number of literates is greater than for those who only attended primary school, but we know that being literate is not indicative of having a higher knowledge level. It is intuitive that a larger intellectual capacity (more s than just literacy) enables these farmers to understand training material as well as lessen their social anxiety when engaging trainers.

The starring variable in the innovation literature is market. As was shown in the adoption chapter, market was a major influence on adoption probability and the descriptive statistics show that it is probably of equal importance for learning. The mean for the export variable is exceptionally higher than for the previous variables; moreover, the non-adopters have the lowest mean amongst all the variables presented, which gives a strong indication that those who do not have access to the crop's intended market have an exceptionally low understanding (this is proven even more by the moderate variation level). This enhances the credibility of the government initiative. Furthermore, this statistic indicates not only a relationship between learning and export market access, but also that the technology is actually effective. If an understanding of the technology is higher for exporters, then those who are more appropriately applying the technology have higher quality crops, hence more access to the export market. This is truly a significant finding as it provides evidence for the most important relationship that the innovation process has established, which is adoption, learning and export market access. Consequently, a better quality product has increased access to the target market. Another point is that export market access could be targeted by the ministry to promote and train farmers since it is a primary instigator for learning. This would substantially increase knowledge levels (as well as adoption) since farmers would understand that it is central to accessing markets.

The next few variables act as a proxy for measuring the sophistication of farmers. These are cuttings nursery, pest scouting, and chemical reduction, with innovation age being insignificant. Out of these cuttings nursery is the most representative, as this technique requires significant sacrifice and effort, and only those that place extraordinary value on

quality would adopt this method. Not surprisingly, those that used this technique have the second highest average knowledge level amongst these variables. Furthermore it has the second highest minimum value, which confirms our suspicions. This can act as a good gauge for whether the population has a strong understanding of the innovation. The remaining proxies are representative of a moderate learning level but they are not as telling as the nursery variable. Another interesting note on these variables is that the minimum value for the pest scouting for non-adopters is 30.7% ,which is the joint highest minimum value. This supports the relationship between planting sophistication and knowledge. However, numerous other variables could cause this result.

Three variables are discussed here: two concern training and the other concerns experimentation. The training variables expectedly have the table's highest means as well as maximum values. In addition, the minimum values show that no one had less than two correct answers whereas the untrained has minimums of zero. This is fitting as the in-depth interviews indicated that farmers frequenting RADA and ASSP are the lead farmers with regards to innovation. The trap experimentation variable provides some interesting statistics. It has one of the highest means, which possibly represents actors who have more initiative, and this personal characteristic drives them to be more ambitious in applying the innovation. Moreover, it is tied for the highest minimum value at 30.7%. This provides more support for the previous statement that farmers who experiment are exceptionally ambitious and interested. Due to this quality they are more inclined to seek information about the technology.

The final two variables are living room ownership and being raised in the area. The former concerns wealth, but there is nothing particularly exceptional about its results. The same applies for the latter variable.

It seems that the most important personal qualities are ambition and curiosity. Being able to successfully capture these characteristics will assist one in determining what the prospective learning levels will be. Also, literacy is not particularly important, but a farmer's level of education is.

5.2 Estimation

The focus on extension stays the same, but the new dependent variable is the knowledge level. This is a simple index constructed from a pheromone trap test created by a plant scientist at RADA and graded by a plant scientist at the national agricultural research centre.

We decided to provide two distinct sets of analysis. The first involves an extensive set of estimations that are meant to pinpoint particular issues of interest. The other is a more parsimonious estimation that is meant to be compared to the network effects estimations. The former will give an intricate understanding of the learning relationships whereas the latter will be used to give a more encompassing view of the influences of learning. Also, for the former each set of estimations will drop variables from the previous set in order to keep them parsimonious and minimize mutlicollinearity with the variables of interest in each respective set. Both estimations are divided into themes: Extension; Market;

Education; Experience; and Group Membership. However, the network estimation does not include group membership as it conflicts with the network variables. The reasons for extension and market inclusion are intuitive as they provide an understanding of the extension and market effects on learning that are assumed to be central. Education is also key as it is often noted that education levels determine whether a farmer engages with training as well as how well they understand it.

The last two sections are experience and group membership. The former is significant to whether or not their familiarity with the crop, innovation and community would influence their competency. It is assumed that those that have more experience with the crop and in particular the innovation would be more competent, but this may not be the case as the innovation and crop have only been promoted in the last few years, hence there may even be a negative relationship. Those that have more experience in the community might only have higher scores because they are more familiar with the extension and informal information sources in the community, thus they could readily identify information sources. The final section regarding group membership simply looks at the significance of ever participating in a labour sharing group. Although this seems to be a network effect it is actually not, because it is not constrained to the time period or community of interest, hence it is not an appropriately identified network interaction. It simply captures whether someone has ever participated in labour sharing in order to understand the influence of a farmer's willingness to trust. The major difference between the estimations is that they have different controls and this is because the parsimonious estimation is used to provide comparison with the adoption estimation, particularly with regards to the networks' effects estimations. However, the dominant analysis here has estimations that were solely designed for understanding the intricacies of learning.

The only estimation used is Ordinary Least Squares (OLS). The model uses the standard OLS specification:

The estimation uses a standard OLS model wherein the left hand side variable is the pheromone trap test score variable and the right hand side holds the exogenous variables and error. It was found from doing a Hausman test that there was not a significant presence of endogeneity (Asfaw, 2010). Moreover, a Breusch-Pagan test showed that the errors are constant. These results minimize the possibility of endogeneity. This indicates that omitted variable bias is unlikely. In addition, a Heckman estimation indicated that selection was insignificant, which directed us to a normal OLS estimation (Asfaw, 2010). A further note is that multicollinearity was dismissed as a problem as the VIF was very low for all estimations.

5.2.1 Extension

Understanding the influence of extension on the adoption process is central to determining how actors learn (Snapp, Blackie and Donovan, 2003). Since extension is the primary information source its relationship with farmers is special. The learning process here is comprised of two main actors: the extension service and the farmer. Aside from these there are a number of actors who sit on the periphery such as development agencies and informal community training sources. It is significant to differentiate these actors in

estimating their influence in order to understand the amount of influence and how they are related. What is of particular importance is the significance of formal training sources. The purpose of the chapter is to understand the relationships of these trainers in order to analyse the locus of the thesis, which is the interaction of informal social influences with adoption and learning.

The estimation focus is on the following variables: RADA contact regarding sweet potato pests; attending training; the number of trainings attended; non-RADA training; and nursery adoption. The controls are age, literacy, household size, acres and export buyers known.

The first three models concern RADA sweet potato pest control contact, training attendance and the number of trainings attended. We will discuss these models together as they concern formal training.

Before discussing the estimates we will define the treatment variables. RADA sweet potato contact pest control involves a direct tie between the actor and the information source. This provides the clearest representation of information transfer from RADA. The issue with this variable is that it does not specify how the interaction occurred, so we do not know if the extension officer came to the farmer or if the farmer made exceptional efforts to contact them. This makes a substantial difference, as the way in which they interact provides a measure of effort. If the farmer accidently encounters an officer then it is learning based on chance rather than a prepared enquiry. Although it accounts for when farmers have had contact with RADA regarding sweet potato pest control it does not give an account of the effort expanded to seek their services.

One variable that does provide an account of direction and effort in seeking information is the training variable. This variable is comprised of two parts; one is simply whether the farmer ever attended a training and the other is the number of trainings attended. In this situation there is an account of effort, because the farmer has to set aside the time to attend the training. Here the farmer displays an eagerness for learning because of the effort made. Moreover, it indicates that the farmer is not intimidated by the experience and is ready to engage trainers. This is a key characteristic, as it was noted by many trainers that because of the social distance and poor education many farmers are anxious about training and find it intimidating. Furthermore, those that attend several trainings are those who do not fear learning advanced techniques and discussing with experts. It is those with the highest training attendance who would be the most adept at learning because they have the most curiosity and the least fear.

All of the control variables have virtually the same results, given in Table 6, excluding the first model wherein age is significant at the 10% level instead of 5%. The treatment with the strongest significance is the number of trainings attended which is at the 1% level whereas the others are at 5%. However the coefficient with the largest change (all are positive) is RADA sweet potato contact, which is respectively followed by training attendance and the number of trainings. The latter is the exception by far, as it only increases knowledge levels by .023, as opposed to RADA sweet potato contact which realizes a change of .117. This clearly shows that RADA sweet potato is capturing a stronger effect, probably because it is a more comprehensive variable since it includes any

contact with an officer. There are three other differences between the estimates. The number of years planting is insignificant for the first model and needing RADA for innovation adoption is at the 5% level instead of 1% in the second model. The last one is nursery adoption and it is only significant in the second estimation.

Based on reviewing the treatments of models 1 through 3 the one of particular interest is the first. The relationship of interest here is that between age, years since first planting sweet potato and nursery adoption. A characteristic that relates all these variables is experience. The former variable is not robust due to its slight significance, but its significance changes with the change of training variables. Age relates to planting experience in that those who are older have less experience with innovation than relatively younger farmers. The relationship of less experience in this case is counterintuitive, as those that have only been planting in recent years (since the introduction of IPM and sweet potato export promotion) are more knowledgeable than more experienced farmers. Here experience is defined either by intensity or quality. Those who have planted in recent years would have planted sweet potato for a shorter time period but they have had a more intensive introduction to the crop because of the promotion and training program that surrounds it. As a result there is a negative correlation between planting experience and learning, as shown by its coefficient. However, the planting experience is insignificant in model 1, which indicates that the RADA sweet potato contact variable is more viable than the other training variables. This is mainly because the experience variable is significant in the following two models. As noted before, these variables represent recent sweet potato experience which in turn represents training, hence the variable that captures more of this effect will account for that variation and render any related variables insignificant. This particularly applies to nursery adoption as only the most sophisticated farmers would adopt a sweet potato cutting nursery. This illustrates the strength of the RADA sweet potato contact variable. The results support the RADA contact variable as the most robust treatment.

There are additional reasons for the difference between the training variable models. It is possible that the unaccounted-for variation influencing sweet potato experience is attributed to interaction with RADA extension officers or some other unspecified training source. This could also indicate that individual extension efforts as opposed to field training are more significant because farmers get one-on-one training (t-test results show that there is a significant relationship between sweet potato planting experience and RADA pest contact). Furthermore, since they receive one-on-one training they can question officers on an array of issues that are specific to their crop and their concerns can be explained physically. Those who have had intimate interaction with officers about pest control would spread that information to other actors in their networks. I am emphasizing this idea not only because it is the crux of the literature, but also since half of the sample contacted RADA regarding sweet potato pests and attended trainings (Bernet et al., 2001), meaning there is not a significant difference between the frequency of the two behaviours in the sample. There is probably some other affect causing RADA sweet potato contact to have a substantially larger influence on learning.

When we compare the third model with the first two we see that the training variable coefficient is substantially smaller but that the significance has increased. The number of trainings attended would intuitively have a stronger fit since it is a more precise variable.

Table 6: Learning – Extension Estimation

Dependent = Trap Test Score	(1)	(2)	(3)
Age	.002(.001)*	.003(.001)**	.003(.001)**
Literate	-.025(.031)	-.027(.031)	-.029(.030)
Household Size	.003(.005)	.003(.006)	.002(.005)
Acres	.001(.001)	.001(.001)	.001(.001)
Export Buyers Known	.032(.008)***	.026(.009)***	.025(.008)***
Innov. Age is Insignificant	.001(.042)	.021(.040)	.027(.038)
RADA SWP Contact	.117(.046)**	-	-
Training Attendance	-	.080(.037)**	-
# of Trainings Attended	-	-	.023(.008)***
Non-RADA Training	.053(.035)	.036(.036)	.033(.035)
RADA Field Visit	.012(.041)	.029(.042)	.014(.041)
Need RADA to Adopt Innov.	-.109(.036)***	-.085(.035)**	-.075(.034)**
Need Info More than Market	-.021(.037)	.013(.035)	.009(.034)
# Years Planting SWP	-.003(.002)	-.005(.002)*	-.004(.002)*
Trap Innovator	-.014(.041)	-.030(.042)	-.027(.041)
Weevil Most Invasive Pest	-.018(.039)	-.058(.039)	-.055(.038)
Nursery Adoption	.039(.042)	.084(.042)*	.058(.041)
Observations	64	64	64
Adjusted R^2	.30	.28	.42

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%.

Although, it is counterintuitive that more training does not result in a substantially higher influence as compared to the other training variables, such relationships can occur. Bandiera and Rasul (2006) show that inverted relationships occur once the need for a resource is saturated. These farmers that have more training may not necessarily be more competent as there may be a threshold for training effectiveness. However, what is more plausible is that the more detailed variable is a truer representation of training influence as opposed to the dummy that recognizes any training attendance.

The next two models highlight information and innovation affinity. The purpose is to look at changes in the specification that are tailored to the training type and other indicators that account for farmers' penchant for seeking training services, the interaction closeness, their own curiosity, and the pest's invasiveness.

5.2.2 Market

Next to extension, market has been the most significant influence on learning. Moreover, it is the most recognized variable in the adoption literature. It is important to understand how it influences farmer learning. Also the primary market variable, export buyers known,

is very significant in both the adoption and learning models. This variable is interesting because it demonstrates not only that the export market is significant to knowledge levels but also that the innovation is effective. Innovation effectiveness is one of the most difficult characteristics to capture as farmers rarely keep reliable records of yields or harvest quality. However, since the trap's principal purpose is to increase crop quality, as to improve export market access, a strong and significant positive correlation between knowledge levels and export market access proves that it is improving crop quality. This is supported by increased export market links increasing levels of competence.

Table 7: Learning - Market Estimation

Dependent= Trap Test Score	(1)	(2)	(3)
Age	.002(.001)*	.002(.001)	.002(.001)
Literate	-.030(.032)	-.023(.035)	-.028(.036)
Household Size	.004(.005)	.005(.006)	.005(.006)
Acres	.001(.001)	.002(.001)	.002(.001)
Export Buyers Known	.031(.009)***	-	-
Innov. Age is Insignificant	.007(.043)	.017(.047)	.063(.043)
RADA SWP Contact	.113(.046)**	.100(.050)*	-
RADA Market Advice	-.032(.044)	.008(.046)	.014(.047)
Market Perception Poor	-.040(.045)	-.082(.047)*	-.101(.049)**
Market Perception Satisfactory	-.046(.049)	-.079(.053)	-.084(.055)
Market Perception Very Good	-.053(.049)	-.085(.053)	-.085(.055)
Non-RADA Training	.069(.037)*	.055(.041)	.059(.042)
Need RADA to Adopt Innov.	-.104(.039)**	-.060(.040)	-.046(.041)
Need More info than Market	-.021(.038)	-.023(.041)	-.011(.039)
# Years Planting SWP	-.003(.002)	-.003(.002)	-.003(.003)
Weevil Most Invasive Pest	-.023(.040)	-.044(.043)	-
Nursery Adoption	.042(.042)	.060(.046)	.077(.045)
Observations	64	64	64
Adjusted R^2	.28	.15	.06

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%.

As with all the estimations, the focus of the models is on understanding information and innovation affinity. The focus is on trying to uncover what attracts or repels their affection towards information and technology. As compared to the extension estimation we unfortunately do not have a plethora of market variables. The only other significant market variables asides from export market buyer are the farmers' respective market perception rankings (poor, okay and very good). Also, a less significant market variable is the choice of information or market extension support for the crop. All results are displayed in Table 7.

The first model is used as a control where none of the market perceptions are significant. The second model shows a substantial difference in significance simply by the removal of the export buyers variable. What is particularly significant about this is that the local buyers' variable was never significant for any of the estimation and had no effect on the other variables, thus it was excluded. This shows the insignificance of the local market in

learning. It is something that is expected as the local market takes substantially lower quality potatoes, hence exceptional competence is unnecessary.

When the export market variable is excluded, the results change substantially. The only significant variables are RADA contact and a perceived poor market. The latter is an indicator of whether or not the farmer has been able to sell their crop. The coefficient is negative and substantial thus indicating that poor market access is related to lower knowledge levels. Moreover, there was a significant increase in the power of the estimate as the coefficient doubled.

For the third model the weevil and RADA contact variables were excluded, and in the results the significance and the coefficient size increase substantially. These variables represent different pressures on learning. RADA contact is a learning source, and it applies external pressure on the farmer, whereas weevil infestation is an internal pressure that pushes a farmer to learn. Both of these variables put considerable pressure on the actor to engage in learning. Interestingly, excluding both these variables produces notable changes in the RADA poor market estimate. The poor market variable represents a farmers' ability to access buyers and to sell their crop. There are a number of reasons why farmers would not have good market access. They may not have farmer friends who can help them to find buyers; they may be new entrants into the market, or have poor quality crops. Farmers mentioned in the interviews that traders sometimes use other farmers to vouch for a seller, so it is important to have substantial networks to elevate your status amongst buyers. The first reason is probably the most likely, as getting access to markets is based on social networks rather than one's individual ability to market a crop. Having sufficient social capital is very significant since there is not a unifying network, such as a trading exchange, that permits farmers to find markets independently. This means poor market access can be representative of a low network degree and possibly being a network outlier.

5.2.3 Education

Another important variable is education. which is another major focus in the literature (Alene and Manyong, 2007). There are only a few education variables. The treatments used are literate, primary education, the most popular primary school, and secondary education. We alternated the use of RADA sweet potato contact and training attendance throughout the estimations. The reason for this is that they respectively represent intimate and distant training methods. Those that are more educated will be more inclined to learn from less intimate training as they are more comfortable with an academic or training environment. This contrasts with an uneducated person who is intimidated by the sophistication of language and the presentation method, thus leading them to more intimate and personal training styles. The idea is that those who are educated need less effort to learn, which makes group learning more efficient. The way to compensate for the lack of education is by providing additional time in a more personal and less intimidating setting. Providing a contrast between the two teaching methods will give an understanding of how education is significant to determining the needed intimacy and effort in teaching. The estimation is split into two sets of models in Table 8: models one to four concern secondary education; and models five to eight concern primary education.

The first model shows that secondary education is insignificant, but in the second model it becomes significant when RADA contact is replaced with training attendance. What is particularly telling about the second model is that virtually all the variables that represent farming sophistication are significant. These estimations for RADA contact and training attendance give a different understanding of how they influence learning as the estimates are slightly different with training attendance having a larger coefficient and being more significant. The previous perception of this relationship was that RADA contact represented a more intimate training, which resulted in stronger and more significant coefficients; however, the relationship here is reversed. It is foreseeable that the change in relationship is due to the education variable. In addition this model shows that training attendance is more significant then shown previously and that the educated probably have a more intimate relationship with extension. This provides support for the prevailing position in the literature that the educated interact more with extension (Hussain, Byerlee and Heisey, 1994). Furthermore, those that attend trainings are probably less educated. This is interesting as it was assumed that the opposite would be true, since farmers would want to learn in a more private setting. However, this is not the case as even the larger coefficient gives support to the less educated attending training, as there would be a large change in their knowledge levels since they are starting from a lower position.

Literacy is negative and weakly significant in the first two models, whereas secondary education is strongly significant and positive in models two and three. The significance of secondary education in model three indicates its correlation with wealth variables, acres and hospital fees, since it is insignificant in model one. This indicates that wealth and education are related. Its exclusion does not particularly influence the training attendance estimation, but the RADA contact estimation displays a renewed significance of secondary education. This illustrates that there is a relationship between RADA contact, secondary education and hospital payments. Another note is that there is a substantial change in the hospital variable. It is positively related to farming and innovation investment. This is potentially due to extension bias, minimal risk aversion, and greater endowments (Feder and Umali, 1993). This gives some credence to the point that wealth is correlated to extension, meaning there is either bias in the distribution of extension services or the wealthy contact them more often. However, there are a few people in the study who have substantial land or wealth, hence it is likely that RADA does focus on wealthier farmers. This may also be due to their political position in the community. Moreover, RADA officers may fear the wealthier farmers because they simply have more influence, and to protect their job they ensure that those people are well supported. Furthermore, they may actually be directed to ensure that those farmers are given exceptional support by their managers as they may influence their superiors' position.

The remaining estimations regard primary education. A number of modifications were made to highlight any significance in the primary education treatment. The premise of the change of variables is that information and innovation affinity are strongly related to education as are educated are more capable learners. The coefficient for the primary variable is only significant in the training attendance estimation and is negative. The result indicates that less education reduces learning. However, at the same time literacy is negatively related as well. From simple t-test calculations it is shown that

Table 8: Learning - Education Estimation

Dependent= Trap Test Score	(1)	(2)	(3)	(4)	(5)	(6)
Age	.003(.001)**	.005(.001)***	.004(.001)***	.005(.001)***	.002(.001)*	.003(.001)**
Literate	-.053(.031)*	-.059(.029)*	-.045(.032)	-.049(.031)	-.025(.029)	-.025(.031)
Household Size	.005(.005)	.006(.005)	.002(.005)	.003(.005)	.006(.005)	.007(.005)
Acres	.001(.001)	.001(.001)	-	-	.001(.001)	.001(.001)
Export Buyers Known	.036(.008)***	.031(.007)***	.034(.008)***	.028(.008)***	.034(.008)***	.031(.008)***
Innov. Age is Insignificant	.000(.040)	-.000(.035)	-.002(.040)	.013(.038)	-	-
RADA SWP Contact	.101(.044)**	-	.117(.044)**	-	.121(.038)***	-
Training Attendance	-	.114(.033)***	-	.091(.035)**	-	.079(.034)**
Primary Education	-	-	-	-	-.043(.032)	-.058(.032)*
Mountainside Primary School	-	-	-	-	-	-
Secondary Education	.064(.039)	.081(.037)**	.078(.038)**	.094(.039)**	-	-
Non-RADA Training	.045(.033)	.019(.032)	.054(.034)	.036(.034)	-	-
Need RADA to Adopt Innov.	-.105(.033)***	-.082(.030)***	-.110(.033)***	-.079(.031)**	-	-
Need More Info. than Market	-.001(.035)	.038(.031)	-.012(.035)	.024(.034)	-.038(.035)	-.004(.035)
# Years Planting SWP	-.003(.002)	-.005(.002)**	-.003(.002)	-.005(.002)**	-.003(.002)	-.004(.035)
Weevil Most Invasive Pest	-.024(.037)	-.068(.035)*	-.021(.037)	-.069(.037)*	-.020(.037)	-.054(.038)
Nursery Adoption	.052(.039)	.104(.036)***	.046(.039)	.092(.038)**	-	-
Hospital Fees	.059(.033)*	.101(.031)***	-	-	-	-
Observations	64	64	64	64	64	64
Adjusted R^{2-}	.38	.45	.36	.36	.25	.24

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%.

only secondary education has a significant difference with literacy (those that attended secondary school are more literate).

5.2.4 Experience

Experience is divided into four categories: community; farming; training; and innovation. Community concerns the time resident in the research area; farming experience concerns the number of total farming and sweet potato planting years. Training concerns the years since the last group training and RADA sweet potato contact, and innovation deals with the time since introduction to and adoption of the innovation. The innovation and community experience treatments have similar expected relationships. They both tend to be strongly determined by RADA linkages as well as network information links. Community experience regards those that have close ties to the community through their length of stay and the size of their familial links. These people will have more familiarity with the extension officers as well as having strong social networks because of their strong connection to the community. Farming and training experience represent dedication, the value of farming as well as conservatism. Those that have extensive farming experience are more interested in farming as they have invested much of their resources into it and this can be influential in their learning decisions. In addition, those that have extensive experience can be more conservative in applying new techniques due to their lack of exposure to contemporary methods. This contrasts with training experience since the people would be intrigued by technology because they are taking the time to seek out new planting methods. Innovation would include RADA and network links as they are respectively the source and route of dissemination.

Numerous experience variables, presented in Table 9, are used here. Moreover, the estimation is structured similar to the education models by alternating the use of RADA sweet potato contact and training attendance, asides from the final two.

Other variables that define the models are the exclusion of the weevil and labour sharing group variables as well as the inclusion of primary education. Labour sharing for both the introduction and contact variables is excluded as the treatment becomes strongly insignificant. This variable represents older and more dedicated farmers as it is a strongly traditional institution that has waned in recent years. Since those that had early introduction are older and more established farmers, the labour sharing group would capture this in its inclusion and render it insignificant. Although counterintuitive, the data indicates that those who have planted for fewer years and who have planted fewer crops are those plagued by weevils. This could illustrate that due to significant escalation of sweet potato planting over the last five years that there has been a coinciding increase in pest infestation. The variables are capturing the variation of sweet potato farmers in the period in which it was promoted and training was provided. The next pair of estimations regards years of farming as the treatment. This is simply the number of years that a farmer has been farming independently for the market. This is opposed to those who have only recently engaged in farming as their livelihood, and have not developed the regard and respect for it that long term farmers have. Such new entrants may be less dedicated,

Table 9: Learning - Experience Estimation

Dependent=Trap Test Score	(1)	(2)	(3)	(4)	(5)	(6)
Age	-	-	.001(.001)	.002(.001)	.002(.001)	.003(.001)**
Literate	-.039(.030)	-.044(.031)	-.029(.029)	-.030(.029)	-.046(.031)	-.035(.030)
Household Size	.007(.005)	.007(.005)	.005(.005)	.005(.005)	.005(.005)	.007(.005)
Acres	.001(.001)	.001(.001)	.001(.001)	.001(.001)	.002(.001)	.000(.001)
Export Buyers Known	.039(.008)***	.039(.008)***	.033(.007)***	.032(.008)***	.033(.008)***	.030(.008)***
Innovation Age is Insignificant	.002(.040)	.024(.040)	.034(.039)	.048(.036)	.033(.038)	.054(.038)
RADA Sweet Potato Contact	.086(.041)**	-	.075(.042)*	-	-	-
Training Attendance	-	.036(.034)	-	.056(.033)*	.061(.034)*	.062(.034)*
# Years Living in Hounslow	-	-	-	-	-	-.002(.001)**
# Years Farming	-	-	-.003(.001)*	-.004(.001)***	-	-
# Years Planting SWP	-.001(.002)	-.002(.002)	-	-	-	-
# Years Since Intro. to Trap	.010(.006)	.011(.006)*	-	-	-	-
# Year Since RADA Contact	-	-	-	-	.015(.009)*	-
Past Labour Sharing Member	-	-	.070(.034)**	.060(.035)*	-	-
Need RADA to Adopt Innov.	-.110(.032)***	-.095(.032)***	-.098(.033)***	-.076(.032)**	-.073(.032)**	-.073(.032)**
Weevil Most Invasive Pest	-	-	-.023(.033)	-.040(.033)	-.051(.035)	-.039(.034)
Primary Education	-.045(.032)	-.055(.032)*	-	-	-	-
Native to Area	.086(.036)**	.101(.036)***	.069(.035)*	.081(.035)*	.092(.036)**	.090(.035)**
Numerous Relatives	-	-	-	-	.038(.032)	.033(.032)
Observations	64	64	64	64	64	64
Adjusted R^2	.37	.33	.40	.40	.33	.36

Notes:.* significant at 10%, ** significant at 5%, *** significant at 1%.

as well as being less engaged with agricultural support as they may only be planting for 'catch crops'.

The final two estimations regard two different treatments: time living in Hounslow and number of years since RADA contact. The latter was shown to be significant and positive with the use of the community strength variable. The estimate means that those who have had more years since their last RADA sweet potato contact are more knowledgeable. This could simply be due to experience, thus those who were trained and then built their knowledge through application are more understanding of the traps. The last estimation regarding length of time in the community is negative and has strong significance. The coefficient is small but indicates that those that have been living in the area longer are less competent.

An interesting point to note is that the variables for years since introduction and RADA contact have positive estimates, as opposed to planting and farming experience which have negative estimates. There are a number of issues involved here. For both the introduction and RADA contact variables, those who adopted first are probably more keen and dedicated farmers, as well as being more mature (also another reason was field location, as those who have fields that are more visible are targeted to ensure that as many farmers as possible will observe it). In addition, those who adopt have preferential market access due to the innovation's improved crop quality.

5.2.5 Labour Sharing Member

Labour sharing groups in Jamaica are a fading institution that used to be commonplace for reducing labour costs and increasing the general efficiency of the farming community. Over the years, particularly in the last decade, many farmers and government workers have noted that it has become irrelevant due to the seemingly unexplainable deterioration of trust. In the qualitative study it was determined that receding participation is because of the primary participants, older farmers, becoming increasingly fragile and the youth are espousing a more individualistic attitude. Moreover, fewer young people are interested in farming, and those who are mainly engaged in illegal farming. This variable concerns whether or not a person has ever participated in a labour sharing group. Such an entity requires a high level of trust, as all members in the group must reciprocate labour or the agreement falters.

There are a few concerns regarding this variable. Since this is an old social institution characteristics associated with the elderly are thought to be specifically relevant. These regard experience, wealth, age, community ties and education. The first model, given in Table 10, is used as a base and shows a slightly significant labour sharing variable. In the second estimation the inclusion of the sweet potato planting experience variable increases the significance of the treatment and its size. Previously we have noted that sweet potato planting experience is negatively correlated with learning as more experience decreases learning, since those people are less likely to have engaged in sweet potato training.

Wealth and age are significant as they represent the more able and dedicated farmers in the area. These characteristics are captured by the hospital payments variable. Those that

Table 10: Learning – Labour Sharing Member Estimation

Dependent=Trap Test Score	(1)	(2)	(3)	(4)	(5)
Age	.001(.001)	.001(.001)	.000(.001)	.001(.001)	.002(.001)
Literate	-.021(.030)	-.018(.029)	-.030(.028)	-.023(.029)	-.040(.032)
Household Size	.004(.001)	.008(.005)	.010(.005)	.006(.005)	.003(.005)
Acres	.001(.001)	.001(.001)	.002(.001)	.000(.001)	.000(.001)
Export Buyers Known	.030(.008)***	.029(.007)***	.034(.007)***	.033(.008)	.031(.008)***
Innovation Age is Insignificant	.006(.039)	.017(.038)	.017(.037)	.019(.039)	-.001(.039)
RADA Sweet Potato Contact	.118(.040)***	.117(.038)***	.106(.038)***	.102(.041)**	.115(.041)***
# Years Planting Sweet Potato	-	-.004(.002)*	-.004(.002)*	-	-
Past Labour Sharing Group Member	.066(.034)*	.084(.034)**	.095(.033)***	.055(.034)	.056(.035)
Need RADA to Adopt Innovations	-.118(.034)***	-.116(.033)***	-.124(.032)***	-.108(.034)***	-.113(.034)***
Weevil Most Invasive Pest	-.015(.035)	-.026(.034)	-.013(.033)	-.017(.034)	-.021(.035)
Primary Education	-	-	-	-	-
Native to Area	-	-	-	.065(.036)*	-
Hospital Fees	-	-	.080(.031)**	-	-
Secondary Education	-	-	-	-	.060(.040)
Nursery Adoption	-	-	-	-	.020(.040)
Observations	64	64	64	64	64
Adjusted R^2	.35	.38	.44	.37	.35

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%.

engage in learning have more interest and commitment to farming and this compels them to pursue innovation. Moreover, it is more significant to their household income than the younger farmer who focuses on other crops. Labour sharing is a risk-sharing mechanism as the establishment of a group of trusted and respected labourers virtually eliminates the risk of receiving poor quality labour. The variable should increase the significance of the estimate and this is exactly what we find.

Accounting for hospital payments improves the fit of the labour sharing variable and indicates that labour sharing is for less wealthy farmers. Hospital payments represent wealthier farmers, hence it acts as a control. Those who engage in labour sharing want to save money as well, since it only necessitates reciprocating their labour and not their money. It's very strong significance demonstrates that these qualities propel these farmers toward learning.

The next issue is community ties. In order to build trust within a community, especially one that has little migration, you must prove your character (Dasgupta, 2005). This is especially important in resource sharing groups. The members must have a strong reputation for being respectable people that have integrity, otherwise it would not be possible for them to participate. Due to this, there is a strong likelihood that those people are also entrenched in the community. What particularly solidifies this in this cultural context is one’s childhood home and to represent a farmer’s community ties we use the variable for being native to the research area. Its result shows that it substantially reduces the significance of the labour sharing variable as well as its size, which indicates that being raised in the area is related to labour sharing. This illustrates that being an indigenous person in the community is significant to information dissemination and to trust levels.

The last two models concern education. One of the suspicions of the ‘Day for Day’ members is that they are older and less educated. The final model adds nursery adoption and a secondary school education to the base estimation and this eliminates the significance of the labour-sharing group which indicates that labour-sharing members are more educated and sophisticated than one would think. This dispels the assumption that'Day for Day' members are less educated and wealthier. The results suggest that they are more educated and of insubstantial wealth.

5.3 Estimation for Network Analysis

The estimation uses the same dataset as the previous section, which is a cross-section of 64 observations and applies OLS estimation. The same tests used for endogeneity and self-selection in the previous estimations were employed and came to the same result, which is that there is no indication of either. The controls used are: literate; age; acres; household size; export buyers known; hospital fees; children in primary school and weevil as the most invasive pest. Literacy is normally seen as significant to competence as those who read can reinforce their knowledge through literature and in general they would be more comfortable in a teaching environment as they are more academically able. Age was one of the variables noted by the government as significant to learning as it is believed that younger farmers adopt more. This position was supported by the farmers themselves.

However, it is unlikely, as there are few young farmers, since they primarily plant marijuana rather than legal crops. Due to this, the opposite is more probably true. Acres will determine if land is influential. It was noted by some that large landholders were favoured by extension and trainers so it is possible that more land would be significant for higher trap scores. Household size accounts for wealth and household effects that could influence learning. So those who have larger households would be more financially stressed and they would have more responsibility. The next variable is of particular

significance as it will show whether or not the innovation is effective. The purpose of the pheromone trap is to increase access to the export market, hence the number of buyers known is important. The subsequent variable hospital fees represents welfare as those that can support the sick expectedly have substantial wealth. The number of children in primary school is another variable that captures welfare effects since children are normally the most substantial household cost. The final variable accounts for farmers' drive to increase crop value. If a farmer notes that the weevil is the most destructive pest, then they should be eager to learn.

We will begin with the extension model and continue with market which leads to education and experience. The results are displayed in Table 11.

Table 11: Learning Network Analysis Estimation

Dependent=Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.048(.032)*	-.038(.030)	-.044(.031)	-.064(.033)*	-.069(.033)**
Age	.002(001)	.001(.001)	.002(.001)	.003(.001)**	.003(.001)**
Acres	.003(.001)**	.002(.001)	.002(.001)	.001(.001)	.001(.001)
Household Size	.003(.006)	.005(.005)	.004(.006)	.004(.005)	.004(.005)
Exp. Buyers Known	.033(.008)***	.035(.008)***	.036(.009)***	.037(.009)***	.039(.009)***
Hospital Fees	.067(.035)*	.065(.033)*	.064(.035)*	.058(.035)*	.051(.035)
Child in Pri. School	.045(.028)	.021(.026)	.025(.030)	.026(.029)	.011(.029)
Weevil Most Invasive	-.034(.037)	-.009(.035)	-.002(.038)	-.006(.038)	-.027(.038)
Non-RADA Training	-	.017(.036)	.009(.039)	.012(.038)	.020(.039)
RADA SWP Contact	-	.112(.038)***	.115(.041)***	.111(.040)***	.095(.042)**
Need RADA Support	-	.111(.098)***	-.108(.039)***	-.104(.038)***	-.096(.037)**
RADA Market Advice	-	-	-.022(.044)	-.018(.043)	-.022(.044)
Poor Market Access	-	-	-.024(.041)	-.031(.040)	-.019(.040)
Prefer Info. Support	-	-	-.023(.037)	-.017(.037)	-.018(.039)
Secondary School	-	-	-	.062(.040)	.058(.040)
#Years Planting SWP	-	-	-	-	-.003(.002)
#Years Since Trap Intro.	-	-	-	-	.002(.007)
Nursery Adoption	-	-	-	-	.059(.041)
Native to Area	-	-	-	-	.069(.037)*
Observations	64	64	64	64	64
Adjusted R^2	.23	.36	.34	.34	.39

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Extension

Here we find some interesting results. First we will reflect on the difference between control estimates in the first two models. In the first model acres, export buyers known, and hospital fees are significant as well as positive. However, in the extension model, the acres are not significant and this is due to correlation with RADA contact, which indicates a relationship with land. This provides support for farmers who noted that RADA favours large landowners. Asides from this there are no other changes in the controls.

The first extension estimate was expected which is a very significant and positive result for sweet potato advice contact. Those that contact RADA for sweet potato pest advice are more likely to be positively related to knowledge. The next variable non-RADA sweet potato training is actually insignificant, which is unexpected. Non-RADA training primarily regards ASSP and USAID training. It was thought that this would be significant as the ASSP and USAID training was exceptionally thorough and was mostly done in the year where there was the highest number of planters (2005). It was believed that the training in combination with the innovation's dense use would cause exceptional information dissemination, however this was not the case. The last extension variable is the need for RADA support to adopt innovations. This variable regards confidence and is shown to be very significant and negative, meaning that those who are less confident and need RADA support have lower trap scores. This is expected, as people who do not have the confidence to experiment with an innovation or seek counsel with a friend would be less inclined to push themselves to learn a particularly sophisticated innovation. Regardless of whether they seek out RADA they do not possess the necessary confidence to make the effort to be competent in the pheromone trap.

There are not any significant changes in the extension results, aside from a slight reduction in significance in the last two models, and this is because of the inclusion of correlated variables such as nursery adoption and sweet potato planting experience.

Market

Surprisingly none of the market variables are significant. It is only the export buyers variable amongst the controls that is of significance. This is very important, as it shows that export market access is key to learning, which indicates that the innovation is effective. This is an important finding as it validates the introduction of the innovation since its purpose was to increase export market access.

Education

The secondary school variable is insignificant as well, but it is notable that when it is introduced the literacy variable becomes significant. Moreover, the age estimate becomes significant as well, thus acting as a control that is probably captures correlation with another variable correlated with them. What is particularly interesting is that literacy is negative, which shows that being literate reduces knowledge. It is suspected that the

reason for this is that the poor have a high value for farming since farming is a profession of last resort in this context. Those who are of a higher welfare status do not invest as much into farming or dedicate as much time because they do not receive sufficient income from it to do so. This is a position that has been suspected, as poor farmers seemed to be the more competent and dedicated farmers so it was suspected that literate farmers would actually have lower test scores. We can see from the subsequent experience model that the significance is increased even further.

Experience

These estimates do not realize any particularly significant variables except for being from the research area and sweet potato planting experience, but they are marginal. However, they show that being a native member of the community increases your trap score. This gives some indication that strength of ties is significant to learning or, possibly, that they are more related to the training services. Being from the research area is actually correlated to the extension variable, therefore displaying their correlation to one another and showing why the training variable estimate is less significant.

The planting experience is shown to be negative and this is probably because those who have started planting recently were guided by IPM trainers, which means they are more inclined to adopt the innovation and learn. This contrasts with the older farmer who has been planting for decades and is not particularly familiar with the new methods. Thus more experience in this case would actually be related to less knowledge because of the training and promotion period. It is interesting to note that this variable becomes significant and the being native variable becomes insignificant when the labour sharing variable is added. This is because labour sharing members are older. The correlation with being native to the research area would remove its significance and it would act as a control for the experience variable since its relation is with younger farmers.

5.4 Conclusion

This chapter brought forth an array of results, many of which stand out. The extension and market variable results are similar to the adoption estimation in that they are very strong and robust, again showing the significance of market access and extension training to innovation transfer. These results are very important as they confirm that the variables are indeed key to learning (Feder and Umali, 1993). Also, that better export market access is related to higher competency. This indicates that the pheromone trap is improving crop quality since this is what determines export market access.

A new variable for this chapter is needing RADA to adopt, which accounts for a farmer's confidence in applying innovations. This variable captured whether a farmer is sufficiently confident to experiment with an innovation rather than seeking RADA support. It seems to successfully capture this relationship as the variable is robust and strongly negative throughout the models. This indicates that those who have less confidence and prefer RADA support have lower knowledge levels. This risk aversion was discussed in the qualitative work as it was stated that some do not adopt without RADA support. Thus they

do not have the confidence to take a risk, which indicates that they are less willing to pursue techniques above their comfort level. Moreover, this illustrates that those who have less confidence are not receiving sufficient information to be competent in the innovation. This may be due to low network participation, lower training levels, or some other attribute. In the following network chapter this will be explored as I show the relationship between networks and learning. This is an area that should be given further attention in the literature as confidence can be a strong determinant not only of whether a farmer is open to adoption and learning, but also whether they will seek out learning sources. This is central to the innovation process because farmers are unlikely to pursue learning if they are not confident.

A final note is on the difference that was found between individual RADA contact and group trainings. The former was found to be strongly correlated with wealth and the adoption of more sophisticated techniques, which displays a possible divide based on wealth and curiosity between those who are attending group trainings, and those who receive individual support. This is important because it shows either that RADA's individual support is biased, which was noted by several farmers, or that the two types of training simply attract different actors. Substantive proof of these relationships would necessitate further research, but the result is intriguing.

The subsequent final empirical chapter involves the network analysis. This is the heart of the thesis. The adoption and learning analysis were performed to act as controls for this chapter's analysis.

CHAPTER 6

Networks

6. Introduction

The interaction of networks with learning and adoption is the most significant area of this study. The principle concerns are to understand how information is distributed throughout the community, what the central influences are, and most importantly the significance of networks (de Weerdt, 2002; Fafchamps and Lund, 2003; Bandiera and Rasul, 2006; Fafchamps and Gubert, 2007; Yamauchi, 2007; Van den Broeck and Dercon, 2011). The objective is to understand the influence of networks on learning and adoption in relation to extension. The dependent variables remains the same as the respective learning and adoption chapters for our network autoregressive estimations. In addition we apply dyadic estimation to understand the networks of interest for targeting. The chapter will be focused on learning, as that is the relationship of greatest interest where network effects are concerned, but we will also perform the same estimations on adoption.

6.1 Conceptual Background

The purpose of this estimation is to understand the interaction of three potential farmer learning sources: individual experimentation and intuition; formal trainers; and informal trainers. The first source concerns learning without help from another person; this includes secondary learning sources such as literature, but in this context such sources are unavailable, thus it is simply one's own intuition and ability to experiment. The second source concerns any training through an organization from recognized experts in the field, whether a group or an individual source. The last source is any network connection and other informal social relations. An area of great interest is comparing the difference between the influence of networks on learning and that of formal trainers. The idea is to develop some thoughts on the possibility of networks and formal trainers having significant interactions that influence learning. This is significant to policy as it is central to understanding whether networks complement or hinder extension in order to determine if it should be included in their training policy, particularly since the purpose of this study is to determine whether networks influence learning and adoption.

What is of particular importance is differentiating what is known in the literature as learning-by-doing from learning-from-others in order to correctly identify the social effect (Foster and Rosenzweig, 1995). Based on this there are three principal relationships: test scores and learning through intuition; test scores and learning through formal training sources; and test scores and learning through network and informal social relations. Different measures have to be taken for each relationship in order to identify it correctly. For the first relationship, formal and informal social relations need to be controlled for. The next has to account for groups that may include self-selecting members who take formal training. In the final relationship, a concern is vertical influences on horizontal

relationships such as formal trainers, as well as endogeneity by, for example, including group membership.

For all the relationships spatial data is very important, as the mobility of farmers varies since many do not have motorized transport. There is field level GIS data for all fields as well as sweet potato plots. In addition we have the field and home administrative districts. Spatial information is normally important in rural areas because of their mobility restrictions. Other concerns are wealth, education and age interactions, as people often interact along these lines because there is less variation in modes of communication. Additionally, family and being native to the research area would make one have a higher level of trust with others that share these same bonds.

This leads us to one of the most significant concerns of network studies, strength of ties. There are numerous positions on this characteristic (Santos and Barrett, 2007). The one famous position (Granovetter, 1973) is that of the strength of weak ties where it is posited that those who have many weak ties have a higher probability of gaining employment as they give access to a wider array of networks. This would translate here into farmers that have many weak links that provide information. However, it is thought this position is unlikely as this innovation requires substantial training due to its sophistication, meaning that you must have network connections that will devote the time to carefully teach the innovation's application. Strength of ties is measured through a number of observations: trust; speaking frequency; familial relationship; and friendship length. These measures can also be used as controls for network links as those which have very strong trust measures would be more likely to participate in networks, as they are highly trusted. It helps to determine the significance of the interaction because if there are many people involved in a network who are not trustworthy but simply have a sought-after resource or skill, their inclusion in the network will indicate the exceptional value of this resource or skill.

The interests of the adoption estimation differ from the learning estimation. The primary difference between learning and adoption is the time of the behavioural change. The former is over a prolonged period of time whereas the latter is the moment at which the trap is placed in the field. Hence, learning needs strong ties, whereas adoption can be influenced by mimicry. Particular concerns for adoption are spatial influence, particularly observability, as farmers may simply acquire the innovation based on observation.

I will be employing different identification and estimation methods from the previous chapters. First I will provide an introduction to the networks, learning and adoption behaviour through descriptive statistics, then I will discuss the estimations.

6.2 Descriptive Statistics[37]

6.2.1 Data

Three datasets are used in this chapter. The first is a dyadic dataset that is used for network targeting estimation. Dyadic datasets use dyads as observations. Thus the dataset has 4096 observations which is the cross-section of 64 observations squared, since it represents the dyadic links of all observations. Within this dataset there are three different types of variables: differenced individual attributes, summed individual attributes and dyadic attributes. The former are simply the difference and sum of individual attributes for each dyad and the latter are attributes of dyads. For the network targeting estimation the number of observations is 4032 because the diagonal in the dyadic matrix is excluded since those values represent observations' links with themselves, hence they have no real value. The second dataset is for the network autoregressive learning estimation and is the same as the cross-section dataset used in Chapter 5. The third dataset is for the network autoregressive adoption estimation and is the same as the panel dataset used in Chapter 4.

6.2.2 Learning

Reflecting on Tables 13 and 14 we can see that simple statistical measures provide significant information on the relationships between networks and learning. The largest network is Market Sharing and the smallest is Partners. Large network size is assumed to be the most effective at disseminating information as it enables a higher likelihood of interacting with an information link. Based on this, plant material and market sharing are the most likely to be the most significant in influencing knowledge levels. However there are other concerns such as the strength of ties that may be correlated to networks, which is shown in Table 12. The trust level in the community is considerable seeing that many noted that trust is one of the main issues in the area. The mean indicates that there is a relatively strong amount of trust in the community, as the highest value is 5 and the average is 3.67 with a standard deviation of .44, which shows that linked people in general value one another. This result reinforces what was found in the qualitative study. Although before the in-depth interviews many noted in general conversation that trust is a major issue, it was actually found that there was a substantial level of trust. This was tested by discussing money-lending, which is very sensitive in this context, and it was universally noted that money-lending is common. It is possible that the stated recent decline in collective action in the community is due to a shift in demographics (migration, less youth, occupational shifts into illegal farming, etc.) rather than a lack of social concern. Furthermore, the trust indicators show that those with very high trust levels have higher than average scores and that those of very low levels have substantially lower average scores. This is important, as a low level of trust would be likely to deter the spread of information.

[37] The variable descriptions for this chapter along with their corresponding questions in the questionnaires are give in Table 18A in Appendix 4.

The next variable, Speaking frequency, reinforces the importance of strength of ties (Monge, Hartwich and Halgin, 2008). Those who speak on a daily and weekly basis have a substantially higher learning mean. Only the couple of months' frequency is shown to be significantly different in the t-test. The final two points are Gender and spatial variables. Those dyads that are of the Same Gender have a relatively high mean, but this is primarily due to there being a predominantly male presence in the sample so it was inevitable. The spatial variable concerns those who live in the Same Home District and the t-test shows that there is not a significant difference in learning between the two groups, which justifies our use of fields as the significant spatial relationship.

For the network links the general link is shown in Table 14 to have the highest mean and this is expected as it comprises all the networks. As we can see in Table 14, the network with the highest mean is Market Sharing and this reinforces the importance of market access to learning. It is also the second most significant network next to Sweet Potato advice. What is interesting is that the sweet potato advice mean is substantially lower than Market Sharing and even Plant Sharing. There are three networks that are insignificant: Hired Labour, Informal Insurance, and Partners. This was expected as they had low response rates. One network that is particularly strong is Labour Sharing. It was thought that this could be an indicator of social attributes such as trust, age, and livelihood affinity. This variable does not have a particularly high mean but it is very significant, so it may be particularly influential. This is probably due to the strength of ties of network members. A result of the in-depth interviews was that labour-sharing groups have their own faming culture. This group is characterized by more dedicated farmers and an inclusive planting culture which is indicative of more uniform planting methods. This means that these groups could be clusters of adopters or non-adopters. Thus they would be suited for extension targeting. The promotion of these groups by ASSP is probably why it has a strong relationship with learning. The family link is significant as well, but the mean is the lowest of all the significant networks; also, non-family members have a higher mean than family members. I am uncertain why this is the case. It may be that there simply are not a significant number of linked family members who are competent in the technology; for example, the most connected farmers on sweet potato advice have only one shared family member. This is supported by the qualitative work, as it was found that there is not a culture of family farming and that farms amongst family members are independent.

Based on the descriptive statistics it can be assumed that the significant networks are going to be Sweet Potato advice, Market Sharing, Plant Sharing, and Labour Sharing. Furthermore, strength of ties will be significant for trust and interaction frequency. It seems that many of the predictions that were made in the data generation chapter could be fulfilled. As a note, only Sweet Potato Advice, Planting Material Sharing, Market Sharing, Tool Sharing, Labour Sharing and Family networks will be used for estimation, because the remaining networks were too small.

Table 12: Descriptive Statistics - Networks

Variables (all dyads, link=1)	Mean	Std. Dev.	Min	Max
General Link	.114	.303	0	1
Same Home District	.211	.131	0	1
Same Gender	.603	.157	0	1
Trust	3.673	.446	1	5
Speaking Frequency	2.134	.415	1	7
Friendship Length	2.206	8.338	0	70
Sweet Potato Link	.035	.177	0	1
Plant Sharing Link	.059	.224	0	1
Market Sharing Link	.060	.225	0	1
Hired Labour Link	.010	.097	0	1
Labour Sharing Link	.013	.109	0	1
Family Link	.026	.151	0	1
Informal Insurance Link	.010	.097	0	1
Partners Link	.001	.031	0	1
Tool Sharing Link	.032	.166	0	1
Distance	.182	.172	0	1

Notes: 4096 Observations.

Table 13: Descriptive Statistics - Trap Test Scores of Network Attributes

Variables (all dyads, link=1)	Mean	Std. Dev.	Min	Max	T-Test
General Link (n=426)	.081	.254	0	1.461	-7.396
Same Home District (n=426)	.017	.122	0	1.461	-.136
Same Gender (n=426)	.051	.208	0	1.461	-2.919
Trust Very Strong (n=421)	.037	.182	0	1.461	-3.857
Trust Strong (n=421)	.008	.084	0	1.153	2.069
Trust Okay (n=421)	.022	.139	0	1.384	-1.084
Trust Not Strong (n=421)	.004	.059	0	1	1.038
Trust Poor (n=421)	.008	.076	0	1.153	4.469
Speaks Daily (n=425)	.031	.164	0	1.461	-1.281
Speaks Weekly (n=425)	.029	.160	0	1.384	-1.585
Speaks Monthly (n=425)	.009	.092	0	1.230	-.707
Speaks Couple of Months (n=425)	.007	.072	0	1.153	4.038
Speaks 6 Months (n=425)	.0005	.020	0	.971	.218
Speaks Yearly (n=425)	.001	.030	0	1	.902
Speaks Never(n=425)	.001	.027	0	.923	1.529

Table 14: Descriptive Statistics - Trap Test Scores of Networks

Variables (all dyads, link=1)	Mean	Std. Dev.	Min	Max	T-Test
Sweet Potato Link(n=134)	.029	.165	0	1.461	-10.632
Plant Sharing Link(n=219)	.043	.193	0	1.461	-7.549
Market Sharing Link(n=221)	.045	.200	0	1.461	-9.895
Hired Labour Link(n=39)	.006	.073	0	1.461	.471
Labour Sharing Link(n=50)	.011	.110	0	1.461	-9.040
Family Link(n=96)	.015	.103	0	1.230	3.169
Informal Insurance Link(n=40)	.007	.077	0	1.384	-1.106
Partners Link(n=4)	.0007	.023	0	.817	-.197
Tool Sharing Link(n=118)	.024	.147	0	1.461	-6.787

6.2.3 Adoption

Overall there is a high adoption rate for being a link in the captured networks. The adoption rate for being a link is 86.3% and is presented in Table 15. The most glaring result of the descriptive statistics is the density of adoption in each network. Table 15 shows that there is no network with an adoption rate lower than 80%. The network instrument may be biased, as people may have associated links with the innovation. Farmers may have referenced those in the network who have adopted instead of being neutral. However, there could be other explanations, such as more interested and hardworking farmers being more socially active in the farming community, as opposed to those who do not value farming as much and do not have significant interactions with other farmers. These farmers may be less inclined to invest in innovations. A more active and dedicated famer would take the time to learn such a sophisticated innovation.

The strength of ties results in Table 15 are quite telling and are similar to the learning results. Those who are more trusted and have more frequent interactions are more likely to be adopters, hence there is little difference between learning and strength of ties. The only significant t-test value is weekly frequency.

The variables Same Home District and Same Sex show that those in the same home district are not likely to adopt and it is likely that there is a higher probability to meet adopters in fields. This was presumed and was a primary reason for why GIS was only collected for their fields. Ties of only one gender are also more likely to be adopters, which shows the significance of gender interactions.

Table 15: Descriptive Statistics - Adoption Behaviour of Network Attributes

Variables (all dyads, link=1)	Mean	Std. Dev.	Min	Max	T-Test
General Link(n=426)	.863	.343	0	1	-1.400
Same Home District (n=426)	.183(.682)	.387(.466)	0	1	-.104
Same Gender (n=426)	.531(.331)	.499(.471)	0	1	-.687
Trust Very Strong (n=421)	.370	.345	0	1	.464
Trust Strong (n=421)	.097	.388	0	1	1.297
Trust Okay (n=421)	.230	.333	0	1	-.292
Trust Not Strong (n=421)	.057	.200	0	1	-1.630
Trust Poor (n=421)	.111	.319	0	1	-.473
Speaks Daily (n=425)	.327	.338	0	1	-.669
Speaks Weekly (n=425)	.289	.380	0	1	1.958
Speaks Monthly (n=425)	.110	.271	0	1	-1.483
Speaks Couple of Months (n=425)	.094	.359	0	1	.316
Speaks 6 Months (n=425)	.004	.577	0	1	1.193
Speaks Yearly (n=425)	.016	0	0	1	-1.256
Speaks Never(n=425)	.016	0	0	1	-1.273

Table 16: Descriptive Statistics - Adoption Behaviour of Networks

Variables (all dyads, link=1)	Mean	Std. Dev.	T-Test
Sweet Potato Link(n=134)	.873	.334	-36.778
Plant Sharing Link(n=219)	.899	.316	-55.238
Market Sharing Link(n=221)	.877	.328	-54.719
Hired Labour Link(n=39)	.974	.160	-20.056
Labour Sharing Link(n=50)	.960	.197	-22.643
Family Link(n=96)	.812	.392	-26.725
Informal Insurance Link(n=40)	.926	.263	-18.775
Partners Link(n=4)	1	0	-6.309
Tool Sharing Link(n=118)	.881	.324	-33.605

6.3 Network Targeting Estimation

It is important that we understand what determines network membership. Without this understanding we cannot properly determine how networks influence learning and adoption. Moreover, we cannot determine how networks should be targeted. When applying network analysis it is central that we understand what causes the network's composition. This information allows extension network targeting to be tailored. For example, we will know what kind of links form, and actors holding those attributes can be pinpointed. In addition, it allows us to give an enlightened discussion for the network autoregressive estimations.

This section will be divided into two: identification and estimation. The former will review the identification issues relevant to this estimation and will explain the model specification. This will be followed by the estimation section.

6.3.1 Identification

There are numerous methods of inference in network econometrics (de Weerdt, 2002; Fafchamps and Lund, 2003; Bandiera and Rasul, 2006; Fafchamps and Gubert, 2007; Yamauchi, 2007; Conley and Udry, 2010; Van den Broeck and Dercon, 2011). Here we will use dyadic estimation, as we find that it is the most fitting for understanding network membership. The basic principle of dyadic estimation is that the observation of use is the dyad. Thus network relationships are accounted for by the establishment of paired nodes. The main estimation issues for dyadic estimation are identifying model symmetry and correcting standard errors. Since dyads are paired, the model has to be identified in a manner that reflects the relationship of each node to another. For example, there can be nodes that have equal influence on one another (undirectional) or nodes that are directional, thus one node is directing the behaviour of the dyad. The model for this estimation is presented in Figure 6 (Fafchamps and Gubert, 2007).

Figure 6: Dyadic Conceptual Model

(7) $$L_{ij} = 1 \text{ if } B(d_{ij}, 1) - B(d_{ij}, 0) - C(d_{ij}) + e_{ij} > 0$$

$$= 0 \text{ Otherwise}$$

L = Link between Actors

B = Benefit

C = Cost

d = Dyad

e = Error Term

i = Actor i

j = Actor j

As you can see, there is a glaring difference with single actor estimations. Rather than simply having single observations we take the difference and summation of the individual actors' characteristics. There are two characteristics that determine identification: the first is the directionality and the second is network degree. It depends on the influence within the dyad and the number of actors that an actor is linked to. Regardless of whether the estimation is directional or not, in principle it is necessary to capture the difference and summed effects of the individual actors, as they represent costs and benefits of the relationship, which identifies the utility drawn from the pairing. When the dyads are undirectional then the absolute value of the first term is taken as there is no negative effect since the actors are seeking to maximize their utility as a unit. This contrasts with a directional relationship wherein one actor benefits over another, hence the absolute value is not taken as there can be a cost to the relationship. In addition to directionality identification also depends on the network degree. If the network degree does not vary then the second term in the model cannot be identified as there is no additive property to the model. This means that no significant difference can be estimated for determining if the characteristic is more likely to occur for respective dyadic observation, as the degree is uniform (Fafchamps and Gubert, 2007).

Since dyadic observations are inherently dependent, as each dyadic observation has one actor that holds the same characteristics in relation to those remaining in the sample, the errors are not random. This inherent bias has to be corrected and in order to do so we apply the standard error correction method from Fafchamps and Gubert (2007). This method is based on Conley (1999) and provides a way to correct standard errors for spatially dependent data, using a technique based on identifying dependent errors from time series analysis.

6.3.2 Network and Group Definitions

The next concern of network id**e**ntification is determining what constitutes a network and what that means with respect to the estimation process (Durlauf and Fafchamps, 2004). In the empirical network economics literature there are a variety of different ways that networks are defined. There are proxies that act as 'networks' and there is also direct network observation (Durlauf and Fafchamps, 2004). The former can be used for social entities such as ethnic groups, gender, or education. The issue with these studies is that as they use proxies they do not actually capture contextually defined networks. Just because an actor holds a social attribute does not mean that they interact with people who share the same attribute. The actor could even mindfully avoid others that hold that attribute, making such studies unviable. In general such studies do not hold much credibility due to the fundamental issue of the use of secondary data that was not designed for network identification. This is the most central issue in network estimations as creating boundaries and definition what constitutes a network and its identification is imperative to the results being substantive. Due to the relative youth of this literature, many identification issues are open to interpretation. In this study there is more than one definition for social entities with multiple actors. Rather than using a general network definition I created a conceptual framework for identifying network influence: informal networks; formal networks; formal groups; and informal groups.

Informal networks are those that are not recognized by their members. These are the networks of most interest in this study, because unseen social entities can represent more realistic interactions than defined networks. What needs to be determined are the structured social interactions that the participating actors may not even be aware of, as they capture how actors truly interact with one another rather than what is socially acknowledged. The networks that fit this description are: sweet potato advice, plant material sharing, market sharing, hired labour, informal insurance and tool sharing. It is suspected that such networks may hold the most significance as they are found by stripping bare actors' individual and social attributes in order to understand their most significant interactions. This was done through the preliminary census survey and the qualitative survey as they were purported to uncover the true interactions amongst actors. In the initial survey farmers were asked to divulge any known networks in order to have a complete list of all active social organizations. This was very important in order to differentiate how people interacted with one another and what types of organizations were significant in the community. Such information is central to determining how to develop questions for a qualitative study seeking to identify nondescript social networks.

Formal networks are the remaining listed networks: family, rotating credit and labour sharing networks. They are defined as closed because entrance into the network is either without choice or dependent on the approval of all members. However, the connections are discontiguous in that cliques can form. Membership is censored and exclusive. This is a very different relationship from the informal networks (where there are no gatekeepers or guardians that establish barriers to network membership), so the ties in formal networks are assumed to be substantially stronger. This enhances the facilitation of information dissemination and retention, as the networks are primarily comprised of strong ties and the average network degree is low compared with informal networks. Distinguishing these characteristics is significant as there will be a substantially higher affinity for informal networks, however, the potential influence is lower (unless one assumes the Granovetter argument of weak ties). This means that there is more variation in network characteristics, particularly network degree, as there is no censorship in informal networks. Higher trust levels can entail greater resource sharing and higher utility maximization through membership. There may be many who seek membership but cannot achieve it due to the censor or the obligatory unanimity in decision-making. Such groups should be targeted, as they naturally have a higher probability of disseminating and retaining behaviour as a network.

Although most of the literature amalgamates groups and networks, we think that it is important that a distinction is made between these entities. A network is a social structure spawned from the inter-linking of discontiguous social entities whose linked based on a common attribute within a defined interaction space (Wasserman and Faust, 1994; Durlauf and Fafchamps, 2004). A group is a social entity that explicitly discriminates based on unanimously agreed upon entry requirements, but differs from a formal network in that the connections are contiguous, thus individual actors are unable to form cliques linked to a larger entity or network (Manski, 2000; Durlauf and Fafchamps, 2004). Moreover, they hold formal recognition as compared with formal networks. In this context the formal groups are ASSP, Geneva Producer Marketing Organization (PMO), Jamaica Agricultural

Society (JAS) and Water Users' Association (WUA). These groups are exclusive in that actors must meet membership requirements to join.

The sister to formal groups is the informal. These hold the same group definition but do not have formal regulations. An example of an informal group is a neighbourhood watch group. Although the actors are contiguous and have unanimously respected entry requirements, the group is informal since it does not follow strict regulation.

6.3.3 Reflection Problem and Selection Bias

One of the main identification issues is determining whether the behaviour observed from network observation truly captures an actor's or dyad's own actions. The reflection problem discerned by Manski (1993), as discussed previously, is central to identification, hence it is essential to discuss its empirical significance. Since this study uses networks that are properly identified, the reflection problem is not as significant, as each respective observation's network relationship is captured by various social entities, meaning that these nuanced actors do not have the issue of reflecting their own behaviour as it is identified by comprehensive network representation. Based on the primary data that was collected, the endogeneity issue caused by simultaneity of the network effects is meant to be insignificant.

The final identification issue is self-selection. This is the situation where people enter a network or a group because of exogenous or contextual characteristics that are correlated to behaviour, thus causing a bias in the network selection (Fafchamps, 2004). This is a substantial problem because if the network is self-selecting, the actors' behaviour is determined by a common attribute. In this case it does not actually capture the influence of the network. Knowledge from the qualitative study was used to account for all foreseen correlates in the main survey to minimize omitted variable bias. Hence, the models were specified to counter omitted variable bias.

6.3.4 Analysis

Dyadic estimations are used first to understand the influence of extension, learning by doing and trap knowledge on networks. It is central to determining what influences the composition of the network. This will show which networks are biased towards extension and/or experimentation, as well as their relationship to learning. They will be presented in the following order: sweet potato advice; planting material sharing; market sharing; labour sharing; family; and tool sharing. Also, for all the estimations the differenced results will be discussed first and then the level (summed) effects.

6.3.4.1 Sweet Potato Advice

The sweet potato advice links are assumed to be linked to formal training sources, particularly ASSP membership. ASSP is essentially the knowledge centre for the

community, hence it is likely that it will be strongly significant to link formation.[38] Furthermore, advice from ASSP members is likely to be more memorable as it would probably have greater substance and recall may be higher for those advice links. Another interest is the interaction with RADA sweet potato advice. People that have sought out RADA for pest management assistance are possibly more interested in personal support rather than group trainings, as it is a personal service. The main focus in this estimation is to have a thorough understanding of what is significant to link formation in this network with a particular emphasis on the influence on formal training. It is assumed that there will be substantial correlation; if there is not, this will pose many questions. In particular it would mean that advice networks are not determined by an endogenous effect. This would mean that an entity outside of the source, which provides the impetus for interaction, would be of greater significance (exogenous or correlated effect). Before delving into the results we must note the model that is applied. A directional dyadic estimation is applied as there is directionality in the dependent and there is variation in the degree: see Figure 7.

Figure 7: Dyadic Estimation Model

(8) $$Y = \alpha + \beta_1(z_i - z_j) + \beta_2(z_i + z_j) + \gamma w_{ij} + \mu_{ij}$$

Y = Network Dyad

β_1 = Coefficient of Differenced Exogenous Variables

z = Exogenous Variables

β_1 = Coefficient of Summed Exogenous Variables

γ = Coefficient of Dyadic Exogenous Variables

w = Dyadic Exogenous Variables

i = Actor i

j = Actor j

μ = Error Terms

As with all estimations we will begin with the controls and then discuss different variations of the model. The learning controls consist of the following: trap age; acres owned or used; export buyers known; hospital payments; and weevil is the most significant pest. The network controls are as follows: ASSP membership; Community Trainer 1; Community Trainer 2; Individual Support Preferred; same home district; and same gender.

[38] Farmers noted in the in-depth interviews that ASSP is the best source for sweet potato information

The analysis is guided by one overlying relationship, which is the interaction among learning by doing, networks and formal training. There are two sets of controls, those for learning and those for network identification. The purpose of the first control is to control for group effects and the following two controls for vertical social structure. The category of those who prefer farming support without a group structure controls for group and institutional affinity in training, which is significant as some may simply need the reassurance of a formal structure and this relationship accounts for the bias. The last two controls account for interaction that occurs at farmers' home, and gender ties, respectively.

There are several interesting results in the full mode shown in Table 17. A number of individual and network variables were added to the controls. We are interested in several different issues such as the influence of welfare, education, market, experience,

Table 17: Network Targeting - Sweet Potato Advice

Variables	(1) Controls		(2) Full Model	
Dependent: SWP Advice Link	Difference of:	Sum of:	Difference of:	Sum of:
Age	-.013*	.012	.010	-.021
Literate	-.313*	.186	-.131	-.068
Acres	-.029***	.021	-.025	.019
Export Buyers Known	.407**	-.163	.505	-.299
Hospital Fees	.484***	-.291	.577	-.326
Weevil Most Damaging Pest	-.705***	.632*	-.653	.601
ASSP	.397**	.073	.347	-.027
WUA	.056	-.216	-.032	-.173
Community Teacher 1	-.194	.220	-.288	.413
Community Teacher 2	-.140	.409	-.011	.182
Prefers Indiv. Farm Support	.709***	-.868**	.802	-1.064*
Secondary Education	-	-	.1631	-.384
Washing Machine	-	-	.709	-.885
Trap Experimentation	-	-	1.390**	-1.308
RADA SWP Contact	-	-	-1.069**	1.143**
Non-RADA Training	-	-	.313	-.163
Need RADA to Adopt	-	-	.654*	-.624
Nursery Adoption	-	-	.588	-.516
Prefers Information Support	-	-	-.653*	.874
RADA Market Advice	-	-	.355	-.598
Poor Market Access	-	-	1.031	-1.268
Years Planting SWP	-	-	-.009	.019
Time in Research Area	-	-	-.009	.017
Dyad Attributes:				
Same Home District	-	-	-	-1.445***
Same Gender	-	-	-	.926
Very High trust	-	-	-	2.051***
Daily Interaction	-	-	-	.158
Years Friends	-	-	-	.052***
Spatial AR	-	-	-	.151
Observations	4032	4032	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

individualism, confidence, curiosity, community presence, space, experimentation, extension, and strength of ties. There is a great difference with the controls estimation. The most glaring difference is the insignificance of the Acres result. Welfare is assumed in the literature to have a substantial influence on social interactions. Furthermore, in the controls estimations it is shown to be very significant, while in this estimation it is insignificant. The variable Need RADA to Adopt causes the acres differenced result to become significant, at the 1% level, when it is removed, which indicates that it is correlated to Acres. Acres describes the amount of land that a farmer holds and the need for RADA to assist in adoption describes a farmer's willingness to seek innovation assistance. The latter is viewed as largely capturing a farmer's confidence in and affinity for RADA. A confident farmer is less likely to ask RADA for technological assistance.

Another result that caught our attention is the insignificance of preference in individual farming support. This was strongly significant in the controls estimation. Two variables influential to the variable's significance are RADA Market Advice and Poor Market Access. Once these are removed the variable once again becomes significant, while the removal of nursery adoption and preference for innovation information support also increase their significance. The former variables relate to the farmer's market position. The common characteristics are likely to be non-adoption and being a novice planter. The reason is that those who have not experienced the training benefits of farming groups are probably unfamiliar with market enhancing planting methods. These are novice farmers as only such people seek out RADA for market advice and would have poor market access. It is possible that those who have poor market access do not have substantial social capital. This fits, as those who ask RADA for market information would be more removed from the community where market information is usually found informally. This result was also found in the qualitative study. If a farmer is poorly skilled and poorly connected, it is logical that they would not be significant to this network.

The next major change is Weevil as the Most Damaging Pest variable, which becomes insignificant. Previously, it was significant at the 1% level and showed that the difference in a link made it less likely for advice link formation, which was sensible as it is nonsensical for two people to form an advice link if they both suffer heavily from weevil damage. Two variables that have substantial influence on this result are RADA sweet potato contact and the need to contact RADA for innovation support. This is sensible, as those two variables are more oriented towards the individual. Thus one with extensive weevil damage would seek out RADA.

Export market again shows its significance. With a substantial positive coefficient and a 5% p-value in the control estimations, those with export market access are more likely to form advice links with those without access. This is significant as it directly links what was expected, which is innovation and market advice being provided together. However this is made insignificant with the inclusion of the RADA advice contact variable in the full model.

The next concern is the Hospital Fees variable. Again, this was significant at the 1% level, but has become insignificant here. The RADA Market Advice and Poor Market Access are particularly influential to its significance. As noted before, farmers on the social fringes of

the community have poorer market connections because the community is the primary source for increasing market access. Since large hospital payments are related to age and wealth, this coincides with the characterization we have created wherein those who seek RADA market advice and have poor market perception are social outsiders. So this fits, illustrating why it was significant in the controls estimation.

There are a few remaining variables that were significant in the controls estimation but became insignificant in the comprehensive one. These are ASSP membership, age and literacy. ASSP significance is strongly related to trap experimentation, which is interesting as it shows that those in the ASSP group are more innovative. I am uncertain if this is intrinsic or a characteristic instigated by the group itself. However it is reasonable, as the group advocates innovation and may increase confidence due to the exceptional training that is given. Age is shown to be significant to the Need RADA to Adopt variable. As this variable represents confidence in and attraction to RADA, it may be that older farmers are not as confident in innovations, since they are used to less sophisticated techniques. The last variable is literacy and as expected this is correlated with secondary education, which eliminates its significance.

There are a number of other interesting results in the main estimation: Trap Experimentation; RADA Sweet Potato Contact; Need RADA to Adopt; Prefer Information Support; Same Home; Very Strong Trust; and Number of Years Friends.

Trap Experimentation is the variable that captures learning by doing. A link between experimenters and non-experimenters increases the likelihood of a sweet potato advice link. Moreover, the coefficient is large, positive, and significant at the 5% level. It actually has the second highest coefficient, which emphasizes how relevant the attribute is. What is important is that it shows the interaction between learning by doing and network formation. It is expected that those who hold sufficient initiative to experiment with a technology have a natural curiosity which propels them to investigate further through social networks and other training sources. It is significant to understand that innovation adoption is complex in that it is not only formal, informal or individual training that make one competent, but the interaction of the three. In actuality what needs to be understood is what is significant to each conduit of learning, as there may be such things as personality traits that are attributes common to all.

RADA Sweet Potato Contact is negative with a large coefficient and significant at the 5% level for the differenced and the same but positive for the summed variable. This means that dyads of farmers contacting RADA and those who have not reduce the probability of advice link formation, and linked RADA contact farmers increase the probability of an advice link. This is discouraging when considering general diffusion as heterogeneity in advice links is sought because it expedites dissemination. If it is the case that RADA Sweet Potato Advice dyads increase link formation, that means there is clustering in the community; and this causes barriers in the community, since information concentrates. This reinforces the qualitative result wherein it was found that more knowledgeable farmers are likely to interact more, particularly those who have frequent RADA contact.

However, this may also indicate that there is a significant correlation with those who prefer individual training support. It is possible that those who received RADA sweet

potato advice are more individually minded and less keen on sharing and training than other farmers. This may distinguish the types of training as personal oriented (RADA) and group oriented (ASSP). Such a relationship would be very important with regards to general training strategy. If group-oriented training does spur dissemination in comparison with RADA individual training, that means more resources should be concentrated on group training to hasten the diffusion process.

Need RADA to Adopt is the next variable of concern and the differenced variable is significant and positive. This variable captures affinity towards RADA and confidence. The relationship indicates that a difference between those who need RADA and those who do not increases the probability of advice links. This is interesting, as it is assumed that those who lack confidence would have a stronger need for RADA support and this means that the confident are probably helping the unconfident.

Preference for information support over market support is significant, but the relationship is negative. As a result information and non-information supporting actor links are less likely to have sweet potato advice links. This finding is discouraging, as it indicates that novice farmers are not receiving support from more competent farmers who are only in need of market information. Consequently, the information is not being disseminated to untrained farmers and is clustering. This is an unhealthy network characteristic as it means that networks are consolidating information in certain sections, which not only causes gross inefficiency in information diffusion, but also means that untrained farmers have to work exceptionally hard to learn.

The result of the same home variable verifies the assumption that farmers are not inclined to interact with neighbours. It is foreseeable that there are more commonalities which induce interaction in the fields than at their homes. This would be the reason for the negative result. With that said, the Spatial Autoregressive (SAR) term is actually not significant and represents the distance between sweet potato plots.

Trust is something that is assumed to be a good representation of strength of ties. There was a concern that the instrument would not correctly account for trust; but a robust result is found. A high level of trust is shown to increase the likelihood of advice links, which is an expected relationship, as you would have to trust someone greatly to follow their advice. What is even more significant is that this has the largest coefficient and is significant at the 1% level. Furthermore this result goes against the strength of ties theory of Granovetter, which is also expected, as a farmer must have great respect for a person in order to accept their advice. In addition they must have a strong relationship since it takes considerable time to explain the technology. Since these are low welfare farmers, any change in their crop is a risk, hence they have to ensure that the information that they are receiving is credible.

Another measure of strength of ties is years of friendship. This reaffirms our position that strong ties are central to farmer network training. Although the size of the coefficient is small it has the highest t-stat and is positive.

The next estimations will differ from the advice link estimations in that the trap score variable is included. It could not be included in the advice estimation because of

collinearity and endogeneity issues. The remaining estimations will not be as in-depth as the sweet potato advice network, since they are not endogenous to learning.

6.3.4.2 Planting Material Sharing

Planting material sharing is common as it is normal for farmers to store seeds for their next crop or to permit cuttings by others of their last crops. I was uncertain how well a farmer would have to know someone to trade planting material with them, but based on interviews and general interactions, this network seems to be dominated by weak ties. However this can also depend on the crop; for example, farmers normally have high stocks of planting material for crops like pumpkin and melon, since they are seeds. Crops such as sweet potato and peanut stem from plant cuttings and plantlets, which are in shorter supply and have much greater variation in quality. Plantlets have substantial value and therefore would require a stronger tie between the links. The estimation will maintain the same specification, since planting material sharing is directional and has varied degrees. The results are presented in Table 18.

Age is significant, negative and has a small coefficient in the controls model. This shows that younger farmers are less likely to establish a link with older farmers. In the full model, Age becomes insignificant due to the inclusion of curiosity variables. The holds true for the Preference of Individual Farm Support; thus innovation interest is relevant to age and individuality. These are the only differences between the control and full estimation.

Acres is strongly significant and also has a small negative coefficient which illustrates that farmers who have small holdings are less likely to have a link with farmers who have large holdings. This means that there is division between small and large landholders. This result conflicts with the qualitative interviews, which found that there are no apparent divisions in the community, particularly with regards to wealth. Since this is a network that probably has substantial weak ties, this may indicate that there are insubstantial ties between these two groups because if they were substantial, the difference would not be negative as weak ties are probably more common.

One of the community teachers is significant and positive, and those who recognize this person as a teacher are more likely to have a link with someone who does not. I am uncertain what this indicates. The summed variable for preference for individual is significant and has a large negative coefficient. This means that link formation is less probable with more people that are individualistic.

RADA Sweet Potato Advice differenced contact is significant and negative, illustrating that RADA contact farmers and those who have not contacted RADA are less likely to form links. The summed variable essentially verifies this relationship as it is significant and positive thereby links are more likely with more RADA advice linked farmers. The Trap Experimentation differenced variable is significant too, and it is positive, which indicates that experimenters and non-experimenters are more likely to form links.

The Need RADA to Adopt variable is very significant and positive, hence less confident farmers are more likely to form plant-sharing links with confident farmers. The estimation

shows that plant sharers have substantial links between confident and less confident farmers. Poor Market Access is significant and positive, and this means that farmers with bad market access are likely to create links with farmers who have better market access. This is interesting as it is expected that the planting material sharing and market networks may be related so this may be capturing market interactions. This result gives an indication of altruism, in that lesser farmers are being helped by better-connected farmers.

Table 18: Network Targeting – Planting Material Sharing

Variables	(1) Controls		(2) Full Model	
Dependent: Planting Material Link	Difference of:	Sum of:	Difference of:	Sum of:
Age	-.009**	.014	.008	-.012
Literate	.114	.592	.171	.603
Acres	-.020***	.012	-.030**	.008
Export Buyers Known	.050	-.200	.201	-.554
Hospital Fees	.033	-.426	-.195	-.436
Weevil Most Damaging Pest	-.163	.438	-.114	.548
ASSP	-.135	-.476	-.026	-.608
WUA	-.039	-.460	.037	-.723
Community Teacher 1	-.188	.244	-.336*	.470
Community Teacher 2	.436***	.880	.644*	1.062
Prefers Indiv. Farm Support	.083	-1.176**	.136	-1.074
Secondary Education	-	-	.023	-.614
Washing Machine	-	-	.342	-.415
Trap Experimentation	-	-	.507*	-1.177
RADA SWP Contact	-	-	-.409**	1.014*
Non-RADA Training	-	-	.450	.237
Need RADA to Adopt	-	-	.467**	-.185
Nursery Adoption	-	-	.282	-.621
Prefers Information Support	-	-	-.185	.846
RADA Market Advice	-	-	.214	-.277
Poor Market Access	-	-	.624*	-.841
Years Planting SWP	-	-	.013	.027
Time in Research Area	-	-	-.019**	.005
Trap Test Score	-	-	-2.167**	1.308
Dyad Attributes:				
Same Home District	-	-	-	-.104
Same Gender	-	-	-	.974
Very High trust	-	-	-	-.227
Daily Interaction	-	-	-	.365
Years Friends	-	-	-	.069***
Spatial AR	-	-	-	1.054
Observations	4032	4032	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Another very significant variable is the Time in Research Area. It is negative, which means that that links between new and older residents are less likely. Although the coefficient is small it shows that farmers in this network are not as inclusive. Thus plant sharing, like RADA contact, causes divisions in the community.

The learning variable (Trap Test Score) is significant, with a very large coefficient, but is negative. In this case, less competent farmers are less likely to create links with more competent farmers. This means that this network should not be targeted for training, as it is divisive. These relationships are important, as they show how learning is influential within networks.

As noted before, I suspected that this network would be dominated by weak ties; and this is shown by the insignificance of the Strong Trust variable. Daily interaction with the link is insignificant too. However the Years Friends variable is extremely significant, as it has the highest t-stat, although the coefficient is small. The length of friendship increases the likelihood of a link and shows that even though many of the results have pointed to weak ties, links may need to be familiar with one another.

A result that I am unsure of is Community Teacher #1. The result is significant and negative, so links between those who perceive him as a teacher and those who do not are less likely. It is possible that the different results for the teachers are due to their personalities and the respective affinity of the respondents.

The final concern is space. The home variable is insignificant, showing that planting sharing is not significant to neighbour sharing. In addition, the SAR term is also insignificant, hence spatial effects are insignificant in general regardless of whether they are home or field interactions.

6.3.4.3 Market Sharing

This network is believed to be strongly significant to learning, since in the adoption and learning chapters, export market access has shown itself to be very significant and influential. It is particularly important to understand what determines its formation. This network is likely to be dominated by strong ties, as market sharing would require a higher level of trust.

For the full model there are a few notable results shown in Table 19. A very strange result is that the variable Export Buyers Known is not significant to market sharing. This is the most significant market variable, but it is odd that it is not significant to the formation of networks. With regards to the controls, the only variables that changed were age difference and the individual preference level effect. Age is apparently strongly correlated to the curiosity variables, particularly Nursery Adoption. The curiosity variables are also correlated to the Prefers Individual Farm Support variable and this may be due to confidence, which stems from individual training from RADA, as discussed in the Sweet Potato Advice section.

Here the Trap Experimentation variable is insignificant. Those farmers who are confident enough to experiment on their own are not significant to link formation. This differs from the previous two networks. It is unclear why this is so, because it was thought that Trap Experimentation would be significant as market sharing accounts for strongly directional relationships, since those with good market access are going to be confident. The differenced variables would indicate that farmers with low and high confidence form market sharing links. Otherwise, I am not certain why this variable would be insignificant.

Table 19: Network Targeting - Market Sharing

Variables	(1) Controls		(2) Full Model	
Dependent: Market Sharing Link	Difference of:	Sum of:	Difference of:	Sum of:
Age	-.010**	.007	.000	-.029
Literate	.078	.497	.133	.600
Acres	-.021***	.014	-.028*	.014
Export Buyers Known	.044	-.166	.119	-.593
Hospital Fees	.002	-.437	-.213	-.452
Weevil Most Damaging Pest	-.202	.581*	-.089	.802
ASSP	-.047	-.513	-.106	-.709
WUA	-.029	-.243	.010	-.546
Community Teacher 1	-.158	.142	-.210*	.382
Community Teacher 2	.429***	.815	.622*	1.103
Prefers Indiv. Farm Support	.097	-1.154**	.227	-1.039
Secondary Education	-	-	-.166	-.796
Washing Machine	-	-	.473	-.459
Trap Experimentation	-	-	.250	-1.605
RADA SWP Contact	-	-	-.662***	1.014
Non-RADA Training	-	-	.453	.261
Need RADA to Adopt	-	-	.680***	-.164
Nursery Adoption	-	-	.241	-.732
Prefers Information Support	-	-	-.186	.875
RADA Market Advice	-	-	.216	-.277
Poor Market Access	-	-	.566*	-.858
Years Planting SWP	-	-	.027	.025
Time in Research Area	-	-	-.019**	.009
Trap Test Score	-	-	-1.063	1.951
Dyad Attributes:				
Same Home District	-	-	-	-.425
Same Gender	-	-	-	1.428**
Very High trust	-	-	-	.060
Daily Interaction	-	-	-	.902
Years Friends	-	-	-	.077***
Spatial AR	-	-	-	1.119*
Observations	4032	4032	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

The differenced RADA Contact variable is very significant and negative, showing that farmers not contacting RADA are less likely to form links with those who do. This reinforces the possibility of there being clustering of farmers who interact with RADA. Furthermore, due to the significance of the variable and its size, the clustering in this network is possibly exceptional. There could be a host of reasons for why it occurs. One of the main reasons is that those who interact with RADA have better market access due to their crop quality. Since the innovation is exceptionally sophisticated, it is necessary to receive exact information from extension for its application. This would lead to better markets, as market access is determined by crop quality. The concern here is that there is clustered information sharing, which has caused a divide in the community network. This can cause concentrations of markets and information. If market information was divided, but innovation knowledge was distributed evenly, there would not be an issue because

farmers would naturally build markets based on word of mouth concerning market quality. However, if the market and training divisions are linked, this may marginalize a substantial portion of the community and severely stifle their ability to access information and markets.

The learning variable is insignificant, which is surprising, as I strongly suspected that learning would be very significant to market sharing. Even when a number of variables that would prospectively be correlated are removed, it only becomes marginally significant.

The Need RADA to Adopt variable is very significant, positive and has a large coefficient. This means that links are more likely between high and low confidence farmers. Although the RADA contact result shows that there may be a division based on social status, here we find interaction between assertive and low confidence groups. Findings such as these indicate that subtle personality characteristics such as confidence can reveal network attributes. Since this result is more visceral than the significance of link formation regarding landholdings, it gives a better representation of the interaction. If high and low confidence farmer links are more likely to form market sharing links, this is beneficial, as it probably helps market access and consequently learning. This result is further supported by the poor market perception variable which is significant and positive; this shows that better and poor market access farmers are more likely to form a link. As a crop's marketability is strongly determined by its quality, those who produce high quality crops will have more confidence in their crop and hence have better market access. In addition, a more confident farmer is more likely to report good market access. This network probably has an important diffusion characteristic, which is that heterogeneity in ability instigates a positive diffusion rate and a fast convergence rate.

The final differenced variable of significance is Time in Research Area (Hounslow). This result is significant and negative, indicating that newer residents are less likely to form links with more long-term residents. This is significant, as it shows that there may be an issue of trust with regard to people who have not lived in the community for long. While this is perhaps to be expected, it may mean that new farmers have less access information about markets and innovation. In consequence, a group of people is marginalized.

For the network variables, those with the Same Gender are shown to have a significant and positive result with a large coefficient. This may indicate that men hesitate to share networks with women, perhaps simply due to ego as they would not want a woman to surpass them. As a result they would concentrate market information sharing among themselves. It was not thought that gender would be significant to networks, but it is apparent here. A very interesting result is that high trust levels are not significant. Due to the assumed sensitivity of market exchange, this is surprising. It means that market sharing is not something that people were keen on protecting. There were those who noted that they are open to sharing markets but many were hesitant. It was thought that trust would be of substantial importance, but this shows that it is not. This is a positive result, as it means farmers with good market access are more open to sharing it.

A similar strength of ties variable, Years Friends, is very significant and positive. I am not sure how to interpret this result, because Years Friends is represents tie strength, as it

contrasts completely with the trust variable result. However it does support our qualitative result, which is that tie strength is significant to network access, particularly at times of social interaction.

The final concern is space. This is the first network that has had a significant SAR term. It is positive, meaning that the closer that farmers' fields are to one another, the more likely the farmers are to form market sharing links. The coefficient is large and shows a substantial influence; however it is only significant at the 10% level.

6.3.4.4 Tool Sharing

This network concerns the loan of farming tools. When we first carried out the survey, interviewees mentioned, during in-depth interviews about trust issues, that some people 'would not even lend a cutlass' due to lack of trust. We decided to pursue this by having farmers tell us the farmers they would share tools with. The difference with this network and the others is that it does not have a defined role. Planting material and market sharing would be more stable networks, as people would return regularly to the link based on the quality of the material or information. This is opposed to borrowing common tools such as a cutlass (machete), hoe or pesticide sprayer. The only tools that are exceptional and strengthen the tie are motorized tools, but very few farmers own these tools as they are exceptionally expensive. Hence, this network is more subtle and variable (with regards to link attributes). The advantage of this is that it captures the sensitivity of learning to networks. For example, we could view family and labour sharing as the networks with the strongest ties. With such networks it is assumed that if there is information available to be shared, it will be due to mutual concern for one another's welfare. For the models a directional specification is maintained and the results are presented in Table 20.

In the full model there are a number of different results. The only control of significance is Acres and it is negative. The insignificance of the Age variable is due to the Nursery Adoption variable. This points to a relationship between age and innovation sophistication as well as the innovation's training sources, ASSP and USAID. The next variable, Weevil Most Damaging Pest, is correlated to training sources. This is expected, as those who suffer from weevil damage would have more contact with extension sources. The last control result, Prefers Individual Farm Support, is insignificant when experience and test score variables are added. This connection between individual learning and learning levels has been indicated before.

The differenced variables RADA SWP Contact, Non-RADA Training, Need RADA to Adopt, Poor Market Access, Time in Research Area, and Trap Test Score are all significant. The first result shows that farmers, connected with RADA (whether slightly or strongly) are less likely to form a link. This is significant because it means that this network does not facilitate heterogeneity. Heterogeneous training levels in social structures are looked for because they help accelerate adoption and learning more than homogenous structures in which information and behaviour is exclusive (Munshi, 2004). It is likely that learning would be less significant to this group. However, it is interesting that non-RADA training consists primarily of USAID and ASSP training, and that it is

positive. Those people who attended USAID and ASSP training are more open to engaging with others and in this case helping them with tools. This is probably because farmers who attend these non-governmental trainings would be more interested and also keen to help their fellow farmers.

Table 20: Network Targeting - Tool Sharing

Variables	(1) Controls		(2) Full Model	
Dependent: Tool Sharing Link	Difference of:	Sum of:	Difference of:	Sum of:
Age	-.010***	.009	.012	-.025
Literate	.180	.547	.494	.675
Acres	-.022***	.021	-.039*	.016
Export Buyers Known	.023	-.305	.223	-.642
Hospital Fees	-.026	-.642*	-.262	-.596
Weevil Most Damaging Pest	-.246**	.645*	-.263	.903
ASSP	-.170	-.776	-.039	-.871
WUA	-.114	-.413	.154	-.658
Community Teacher 1	-.027	.527	-.188	.918
Community Teacher 2	.273*	.597	.545	.714
Prefers Indiv. Farm Support	.093	-1.356**	.264	-1.308
Secondary Education	-	-	-.120	-1.003
Washing Machine	-	-	.626	-.622
Trap Experimentation	-	-	.153	-1.608
RADA SWP Contact	-	-	-.624**	1.134
Non-RADA Training	-	-	.696*	.248
Need RADA to Adopt	-	-	.566**	-.313
Nursery Adoption	-	-	.264	-.513
Prefers Information Support	-	-	-.174	1.138
RADA Market Advice	-	-	.244	-.330
Poor Market Access	-	-	.900**	-1.283
Years Planting SWP	-	-	.010	.019
Time in Research Area	-	-	-.023**	.010
Trap Test Score	-	-	-2.402*	1.401
Dyad Attributes:				
Same Home District	-	-	-	1.046**
Same Gender	-	-	-	1.606***
Very High trust	-	-	-	.859**
Daily Interaction	-	-	-	1.115*
Years Friends	-	-	-	.041***
Spatial AR	-	-	-	.876
Observations	4032	4032	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

The Need RADA to Adopt variable is very significant and also positive, so there is a stronger likelihood that confident people will form links with the less confident. This is good, as it means that people who are more assertive are helping those who are less so. Moreover, this behaviour is being facilitated by this network. The Poor Market Access variable is also significant and positive. This result is along the same lines as the Need RADA to Adopt variable, in that the more able are linked with the less able. This is a positive result for learning, as it means that there is no division between the driven people

and those of low ambition, and that the former are helping the latter. The Time in Research Area variable is significant too, but is negative, so new residents are less likely to form links with old residents. This variable is meant to capture community ties and it indicates that there may be some division between new and old residents.

The learning variable (the Trap Test Score) is also significant and is negative, meaning that those who have lower test scores are less likely to link with those who have higher test scores. This is an unfortunate result, as it needs to be positive to increase overall test scores. It explains why the average test scores are so low. Without reinforcement and teaching from more able farmers, a substantial portion of the community will maintain low scores and will not increase their knowledge, thereby impeding the spread and quality of information.

All the network variables are significant and positive. What is surprising is that the network is defined by strong ties such as great trust, years of friendship, and daily frequency of interaction; all are significant. This was unexpected, but an interesting sign that even tool sharing requires high trust levels. An additional point is that home and gender variables are significant. This means such people are likely to be neighbours and of the same gender.

A final point to note is that Trap Experimentation is insignificant to link formation. In previous estimations, such as advice links and planting material sharing, it was positive and significant. Its insignificance here shows the irrelevance of experimentation to link formation, which is a negative quality, as the relevance is important in determining how to target the network.

6.3.4.5 Labour Sharing

The labour sharing network concerns rotating labour organization. This is viewed as one of the networks that would be influential to learning as it probably involves high levels of trust and is seen to include more dedicated farmers. It is becoming an antiquated institution and those who maintain it probably have an emotional attachment to keeping it going. I thought this would inspire them to be more dedicated and hence invest more, so they would be keen on adopting and learning new technologies. One problem with this theory is that those in the labour-sharing network may be older farmers; but I believe that my former reasoning will turn out to be correct, as applying the technology yields substantial financial return and offers further impetus to the emotional incentive.

Another concern about this estimation was its correlation to the training sources, as ASSP created labour sharing groups, which may correlate strongly with this variable as most of the relationships may have grown from it. The estimation will use an undirectional specification, as the link influence is reciprocal since the network is predicated on reciprocating labour.

Table 21: Network Targeting - Labour Sharing

Variables	(1) Controls	(2) Full Model
Dependent: Labour Sharing Link	ABS Difference of:	ABS Difference of:
Age	-.008	.002
Literate	.009	.028
Acres	.026	.027
Export Buyers Known	-.135	-.024
Hospital Fees	-.083	-.145
Weevil Most Damaging Pest	-.494***	-.462**
ASSP	-.561	-.438
WUA	-.183	-.228
Community Teacher 1	-.375	.387
Community Teacher 2	.485	.573
Prefers Indiv. Farm Support	.924***	.923***
Secondary Education	-	-.072
Washing Machine	-	-.662*
Trap Experimentation	-	-.365
RADA SWP Contact	-	-.072
Non-RADA Training	-	.059
Need RADA to Adopt	-	-.114
Nursery Adoption	-	-.524*
Prefers Information Support	-	.261*
Trap Test Score	-	-2.402*
Dyad Attributes:		
Same Home District	-	.765*
Same Gender	-	1.131***
Very High trust	-	.631***
Years Friends	-	-.011
Spatial AR	-	1.004*
Observations	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

In the full model, all of the controls yield the same results as presented in Table 21. There are a few notable results here. Nursery Adoption is significant and negative, as non-adopters are less likely to form links with adopters. This result counts against community learning and is harmful to the spread of information. However, its associated variable, Prefers Information Support over market support is significant and positive. Preference for individually oriented rather than group oriented farming support is very significant and positive. It is odd that this is significant to forming links in a labour sharing group. The result is probably due to disgruntled ASSP members, as the group had many fractions and was disbanded less than a year after I left the country. This experience possibly acted as a disincentive and dissuaded people from wanting to participate in group support. Furthermore, this experience probably reinforced the preference for self-reliance over collective action expressed in the in-depth interviews.

It is indicated that information supporters are more likely to form links with market supporters. This would aid in facilitating the two groups with the most significant pressure on learning. Washing Machine is also significant and negative, meaning that those without a washing machine are less likely to form links with those who have one. This reinforces

the wealth divide in the community. Both Acres and Washing Machine have shown to have negative results with regard to link formation. This is an issue that would need to be recognized by extension, particularly since many feel that the wealthier farmers are given preference. Consequently, a bias would have to be placed on poorer farmers to ensure that information is not being concentrated on and restricted to farmers at a higher welfare level.

Space and trust are both shown to be significant to this network. Both spatial terms are significant and positive. Thus in general, regardless of whether it is in their neighbourhood or at their fields, space is significant to forming labour sharing networks. This means that targeting this group for teaching would increase the rate at which information is shared spatially. The very significant and positive trust estimate confirms that this network requires a high level of trust. However, the Trap Score variable is not significant, meaning that although the network is composed of strong ties, learning is not particularly significant to it. Moreover, RADA Contact and Trap Experimentation are insignificant, which prevents us from labelling this an extension or learning-by-doing related network. Trust is the next issue and it is confirmed that labour sharing requires a high level of trust, as it is very significant. Such a network may expedite the learning process because of the closeness of the links, which is a positive attribute for targeting. The last variable of interest is gender. Those of the same gender have a much higher probability of sharing labour. This is likely due to men and women working in different ways and rates, hence making it easier to form links if people work similarly.

6.3.4.6 Family

Kinship is one of the consistent regressors in network estimations, as this network is ever present in rural communities. It is necessary to capture its influence since it is viewed as central to rural interactions, because resources normally stem from kinship connections (Bandiera and Rasul, 2006; Van den Broeck and Dercon, 2011). They are assumed to be the strongest ties in the community. Learning should be significant here, as tie strength is significant for training a person in such a complex technology. Furthermore, communities can be divided based on family, so spatially and financially communities may be sectioned based on family. This would mean that information would be protected within family in order to prevent competing families from gaining an advantage. The estimation uses the undirectional model, as family network membership is reciprocal, and the results are shown in Table 22.

The only two significant controls are extensive weevil damage and individual training preference. The weevil estimate shows that those who do not suffer from critical weevil damage are less likely to form links with those who do and this is an obstacle to information dissemination. However, the Prefers Individual Farm Support variable is very significant and positive, meaning that actors who prefer individual support are more likely to form links with actors preferring groups. It is uncertain exactly how this relates to learning, aside from the previous reflection on confidence. Those who prefer individual training may feel more comfortable with one-on-one interaction with trainers, while other farmers feel intimidated. Based on this logic, the interaction of the two is positive for information dissemination.

In contrast to the previous full models, this one does not include Time in Research Area of Years Friends, as they were causing singularity due to the similar variation with the dependent. Also there were no changes in the results for the controls except for the Export Buyers Known variable. One of the most interesting results among these estimations is that the Export Buyers Known variable has not been significant except for here, where it is also positive.

Table 22: Network Targeting - Family

Variables	(1) Controls	(2) Full Model
Dependent: Family Link	ABS Difference of:	ABS Difference of:
Age	.009	.002
Literate	.033	.066
Acres	.019	.019
Export Buyers Known	.113	.160**
Hospital Fees	-.048	-.048
Weevil Most Damaging Pest	-.454***	-.465***
ASSP	-.565	-.472
WUA	-.256	-.261
Community Teacher 1	.366	.286
Community Teacher 2	.322	.353
Prefers Indiv. Farm Support	.752***	.745***
Secondary Education	-	-.004
Washing Machine	-	-.736**
Trap Experimentation	-	-.508
RADA SWP Contact	-	-.071
Non-RADA Training	-	.133
Need RADA to Adopt	-	-.122**
Nursery Adoption	-	-.572**
Prefers Information Support	-	.225
RADA Market Advice	-	.179
Poor Market Access	-	-.679***
Years Planting SWP	-	.009
Trap Test Score	-	-.796
Dyad Attributes:		
Same Home District	-	1.307*
Same Gender	-	-.458
Very High trust	-	-.235
Daily Interaction	-	.363
Spatial AR	-	.523
Observations	4032	4032

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Poor Market Access and Nursery Adoption both influence the significance of Export Buyers Known. When both of those variables are removed the third becomes insignificant. The estimate means that farmers less connected with exporting are more likely to form links with those that are more connected. This is a positive result, as it means that there is export trader sharing in this network from the more connected farmers. This will help

increase market access and hence provide an incentive for learning. Because of this, the network would be good for targeting.

The Washing Machine variable is significant and negative, meaning that non-owners are less likely to form links with owners. In previous networks, the Acres variable showed wealth division to be significant. This gives even more support to results showing that the community is divided by its different levels of wealth. The variables of interest, Trap Experimentation, Trap Score and RADA Contact, are insignificant.

The next variables, Need RADA to Adopt and Nursery Adoption are both very significant and negative, and harmful to diffusion as noted before. The Nursery Adoption estimate shows that non-adopters are less likely to form links with adopters. This again is harmful to information diffusion, as nursery adopters are the most interested farmers in the community. The division of these sets of farmers harms targeting potential as those who are most eager to learn would not be keen on passing on their knowledge.

The significance and negative value of the Poor Market Access variable indicates that people with better market access are less likely to form links with those who have poor market access. This again is harmful, as positive links between those with good market access and those with poor access would increase the possibility of market access and consequent learning. This can be seen as contradicting the export market result, but this variable concerns local and export market access, and local market prices are not particularly respected, which could be the reason for the difference. The final variable illustrates that being in the same home district is positive and significant. This is expected, as people in the same family usually live near each other because they live on family land. None of the strength of ties variables are significant, nor is the spatial term.

6.3.4.7 Conclusion

There are a number of interesting results that occurred in these estimations. The most noticeable is the absence of the Adoption variable and this is because it was not significant in any of the estimations, almost regardless of the manipulation of the model. Few of the estimations had significant Trap Experimentation or learning variables, except for sweet potato advice, planting materials and tool sharing. However, they indicated that there is a positive relationship between the differenced variables, thus heterogeneity increases the likelihood of links. The result for Experimentation is encouraging as it shows that the more confident and knowledgeable farmers are teaching or at least connecting with those who are less so. However for learning they were negative, which is discouraging. A few other estimates stood out, for example information heterogeneity elicited different results for RADA and ASSP contact. The former creates exclusive interactions whereas the latter creates inclusive interactions; this possibly indicates that one has an individual and the other a group oriented effect. Also, export market links were positive and significant for the sweet potato advice network, which indicates that advice links are behaving in the ideal way by providing pest and market advice. Another note is that wealth may be a socially divisive characteristic, as land in a number of estimations indicated this, as well as washing machine ownership. Social division through age is also shown to be significant. This shows that there may be divisions that are not noticeable to farmers as they claimed

otherwise during the in-depth interviews. An additional point is that individualistic and confident farmers are not necessarily socially indifferent, as they engage with those who are sociable and less confident. As a final point, trust is shown to be a reliable indicator of strength of ties.

6.4 Network Effects Estimations

A different type of estimator is used for this set of estimations as well as a different dataset. A network autoregressive model, specified in a linear-in-means model, is employed using cross-section and panel data rather than a dyadic dataset (Moffitt, 2001; Lee, 2007; Bramoulle, Djebbari, and Fortin, 2009). What is significant in this type of estimation is an observation's reference group. Each observation has a specific reference group for each respective network. The purpose of this estimation is to determine the significance of networks to learning and adoption. The dyadic estimates will be used to provide an informed discussion about the network attributes and hence what the regressor is truly capturing with regard to network effects on learning and adoption. This is very important for providing a true representation of network effects.

The dependent will be the Trap Test Score. The treatment is the network autoregressive term which is created by the combination of a social distance matrix and the dependent. The social distance matrix is based on the strength of ties, as this was deemed the determinant for the distance between actors. An inverse decay function is used so that the distance measures are proportional to the tie strength measures.

One of the primary concerns of network autoregressive models is endogeneity as the autoregressive term can be correlated with unaccounted attributes that affect it (Lee, 2007). This is common, because social structures and characteristics can often intersect as the autoregressive effect may be due to other influences. The use of the Hausman test in the learning rejected the possiblity of endogeneity. Also, in both the adoption and learning estimations the Breusch-Pagan test did not reject the null of homoscedasticity. This is indicative of no endogeneity, as omitted variable bias causes error dependence, thus instrumentation of the AR term was unnecessary. As noted before a primary concern of network estimation is endogeneity caused by simultaneity and omitted variable bias.

Figure 8: Network AR Learning OLS Model
Learning Model:

(9) $$Y_i = \mathbf{X\beta} + \delta G y_i + \rho W y_i + \mu_i$$

Figure 9: Network AR Panel IV-2SLS Model
Adoption Model:

(10) $$Y_{it} = \mathbf{X_t\beta} + \delta G y_{it} + \rho W y_{it} + \mu_{it}$$

Y = Dependent Variable

X = Exogenous Variables

β = Exogneous Coefficient

δ = Network AR Coefficient

G = Social Distance Matrix

ρ = SAR Coefficient

W = Spatial Weight Matrix

μ = Error Term

i = Network Identifier

t = Year

The purpose here is to capture the endogenous effects (network autoregressive), which is to determine if the behaviour of those in the network vary with one another. We will be using models similar to those in the Learning and Adoption chapters in order to provide a comparison. The first term on the right hand side is the explanatory variable set and the next variable is the network autoregressive term, which is then followed by the SAR term. The network autoregressive term is the combination of the network effect weight, which is the trust level e.g. strength of ties, combined with the mean of the Trap Test Score of the reference group for each observation. The analysis will be split into two sections, learning and adoption. The structure of the estimations will be the same as that in the dyadic section with the respective networks being used in separate estimations. The purpose of these estimations is to understand the significance of the network and training effects. We will begin with the sweet potato advice link and then discuss the planting material sharing, market sharing, tool sharing, labour and family networks respectively. As a note, the learning estimations employ OLS and the adoption estimations use panel IV-2SLS.

6.4.1 Learning

6.4.1.1 Sweet Potato Advice

The estimation will follow the model from the learning chapter with the exception of the interchanging of the Acres and ASSP variables (these model variations are not presented), as well as the removal of the labour sharing variable, since we estimate it as a dependent here. The same controls that are used in the learning estimation are applied, however, and when the Acres variable is removed the endogenous effect becomes strongly significant. Although the endogenous effect is still significant with its inclusion, it is not strongly so. This is probably due to the correlation between trust and acres owned, as farmers with more land may be more respected and trustworthy. However, with the inclusion of the network variables the network effect becomes strongly significant. This is interesting, as we saw in the dyadic estimations that RADA contact could be an indicator of personal-oriented training. As we will show in the following sections, the ASSP variable is strongly correlated with almost all the network autoregressive terms. This is due to the significance

of ASSP for the most socially active farmers since it was a central interaction point. The estimates are presented in Table 23.

As sweet potato training advice is very socially oriented, it may be that the RADA contact variable is acting as a control. This is evident as the inclusion of the ASSP variable shows strong correlation with sweet potato advice links, indicating that sharing of pest management information stems from this group rather than from RADA contact. This reinforces the story that was developing from the dyadic estimation. ASSP membership has stronger links to network information dissemination. This is certainly a valid result as ASSP is also noted in the in-depth interviews as being the best sweet potato information source. However, the concern is why this is so. I suspect that the group orientation provides consistent information reinforcement which encourages farmers to share information with others. For example, in the dyadic estimation farmers who contacted RADA were less likely to form links with those that did not, meaning that there is something preventing them from engaging in information dissemination as compared with the ASSP group. It may be simply that there is less information provided by RADA than by ASSP, hence there is a smaller probability of information being diffused. This can be supported by their respective coefficients.

Furthermore, those that engage with RADA rather than ASSP may have a preference for a personal-oriented service. This is particularly telling as regards the information network development, as RADA contact is not correlated to the network effect. As a result it is not as effective in infiltrating social networks. This points to the ASSP group, which is highly correlated with the group as its introduction eliminates the significance of the sweet potato mean variable. Additionally, it has by far the largest coefficient of the training related variables, which indicates why it would be related to an advice network. If membership in this group significantly increases one's learning level, then those farmers would be most likely to spread the information. The dyadic estimate illustrating that ASSP members are more likely to form links with non-members supports this result by showing ASSP's significance to learning and its correlation with the endogenous effects.

Another variable correlated with this network is the need of RADA support for adoption. This variable has a strong influence on the significance of the network variables as its exclusion causes the variable to become insignificant. Moreover, it is shown that its exclusion when RADA contact and ASSP variables are included makes the RADA contact variable insignificant and the ASSP variable less significant. As a variable that captures confidence it has little relation to the ASSP variable, showing that it primarily captures one's interaction with RADA rather than being a general measure of confidence as was assumed. However, what is interesting is the significant effect that it has on the network effect. It is interesting that these variables are related, since in the dyadic estimation it was shown that the disparity in confidence instigates network links, hence it captures this relationship.

Table 23: Network Autoregressive Learning - Sweet Potato Advice Network

Dependent = Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.032(.033)	-.020(.030)	-.026(.032)	-.046(.034)	-.055(.033)
Age	.002(.001)	.001(.001)	.001(.001)	.003(.001)*	.003(.001)*
Acres	.002(.001)**	.001(.001)	.001(.001)	.001(.001)	.001(.001)
Household Size	.003(.006)	.005(.005)	.005(.005)	.005(.005)	.004(.005)
Export Buyers Known	.032(.009)***	.034(.008)***	.035(.009)***	.035(.009)***	.036(.009)***
Hospital Fees	.055(.036)	.054(.033)	.055(.034)	.049(.034)	.046(.035)
Children in Primary School	.047(.027)*	.022(.025)	.025(.029)	.026(.028)	.008(.029)
Weevil the Most Damaging Pest	-.045(.037)	-.019(.034)	-.016(.038)	-.020(.038)	-.034(.038)
Spatial AR	-.006(.007)	-.008(.006)	-.007(.006)	-.008(.006)	-.013(.007)*
SWP Advice Network AR Mean	.020(.011)*	.022(.010)**	.021(.011)*	.021(.011)*	.011(.011)
Non-RADA Training	-	.018(.035)	.010(.038)	.013(.037)	.017(.038)
RADA Pest Advice Contact	-	.108(.037)***	.108(.041)***	.105(.040)***	.089(.041)**
Need RADA Support to Adopt	-	-.112(.033)***	-.116(.038)***	-.112(.037)***	-.103(.037)***
RADA Market Advice	-	-	-.019(.043)	-.014(.042)	-.016(.043)
Poor Market Access	-	-	-.024(.040)	-.031(.040)	-.019(.040)
Prefer Information Support	-	-	-.011(.039)	-.006(.039)	-.017(.039)
Secondary School	-	-	-	.063(.039)*	.056(.039)
Years Planting SWP	-	-	-	-	-.002(.002)
Years Since Trap Introduction	-	-	-	-	.006(.007)
Nursery Adoption	-	-	-	-	.067(.043)
Native to Area	-	-	-	-	.076(.038)*
Observations	64	64	64	64	64
Adjusted R^2	.25	.39	.37	.39	.42

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

However, when the variable is removed the network effect is insignificant. It is significant in that it shows a personality trait that can strongly influence participation in an advice network. This is particularly positive as it means that those that are less confident are inclined to enter into advice sharing networks. Although the estimate indicates a strong negative relationship with learning, what is significant is that the less confident are engaging in community learning structures. It is not surprising that they have lower learning scores and that confidence is very significant to one's test scores, but what is interesting is that they are engaging in networks. If there was no indication that less confident farmers were engaging with others then it would be worrying as it would mean that they are marginalized. What is even more interesting is that the community and extension have not established barriers, emotional or social, that prevent less confident farmers from engaging in the learning process. If the opposite was the case, it would be a cause for concern. Once the Need RADA to Adopt and the RADA Contact variables are removed, it becomes significant again. This displays the relevance of the RADA Contact variable since, although it may not be as substantial to advice network formation as ASSP, it is still influential.

When the Acres variable is removed the network term becomes significant as the correlation of the Acres variables reduces its significance. This was one of the concerns of the dyadic estimation, wherein it showed that a disparity between landholders makes it less likely for people to form advice links so it may be capturing interactions of landholders of similar size. Otherwise, the effect on extension variables is insignificant.

The market variables' inclusion reduces the significance of the network effect. The variable with the strongest correlation is Prefers Information Support. Those who prefer information support are the more interested farmers. This includes non-adopters and novice farmers as well as those that have exceptional interest in innovation. They believe that a thorough understanding of an innovation can be more valuable than more market contacts. Thus, because of their penchant for innovation, they were thought to be more inclined to spread information. It was shown in the dyadic estimation that the disparity between the interested and non-curious actually decreases the probability of advice links. This makes sense as more interested farmers would seek out similar farmers. However, this is detrimental to network diffusion as those who are interested are the best for disseminating information as not only will they spread information but also they could encourage others to increase their interest. This provides further support for our previous estimate. As a note, regardless of the inclusion of the Acres variable, none of the market variables are significant.

The education variable is next and is shown to be significant with the exclusion of Acres, but not when Acres is included. The network term is still significant with its inclusion, showing particular strength when Acres is excluded. It was thought that education would be correlated with the advice networks, as the better-educated would be more inclined to share information, as they would be assumed to be information sources. However, it is not shown to be relevant. The only point of significance is that when literacy is removed secondary education becomes insignificant, which makes sense because of their

correlation. This result provides further support for the position that education is insignificant as farming knowledge is probably based on one's own dedication to the work rather than on intellectual capacity. This is meant to counter the position in the literature that the more educated are more knowledgeable, as well as providing support for the position that smaller landholders and less wealthy farmers are more active in seeking knowledge and disseminating it due to the importance of the livelihood to their household welfare.

The last set of variables regards experience. It was assumed that those who have more experience would be more inclined to enter advice networks, not because they would want to impart with their greater knowledge levels but because farmers they would be seen as experts and farmers would look to them for advice. Thus they would attract actors to create links. However, this was found to be insignificant in the dyadic estimation and the same result is found here. This is interesting, as in the learning estimation experience was found to be significant in reducing knowledge levels because the more experienced farmers probably had less training on IPM and less interaction with training sources. This illustrates a negative relationship with learning and indicates that the farmers who have entered the market in recent years would be more competent. The variables that show a correlation with the network are Native to the Area and Nursery Adoption.

Community ties are thought to increase the probability of network interaction. If someone has been part of the community from childhood, people would be more inclined to help them. This result can be perceived in a couple of ways. It can be positive, since it shows that the community values native members. This means they are open to sharing which is significant as it was widely noted that farmers are protective of resources. However if they are not engaging new members of the community then it may indicate that the innovation information will cluster only around those who have native ties to the community. As clustering is always a negative sign in diffusion, this finding could be detrimental to learning in the community.

The other variable of significance to the network effect is Nursery Adoption. As this is a variable that represents exceptional interest it is expected that this would be correlated to the network effect. Those with enquiring minds, particularly those who find non-monetary benefit from curiosity, would be more inclined to engage in networks because they want to promote interest in innovation. This is a positive finding for dissemination because it means that the more knowledgeable and intellectually curious farmers are actively disseminating information. This is probably significant due to the link with ASSP. In the dyadic estimation it was shown that ASSP members are more likely to form links with non-members. Hence the promotion of nursery adoption by ASSP is probably where this link formation originates. This again shows the difference between ASSP and RADA contact. Although more farmers have interacted with RADA, ASSP has had a much stronger influence on learning development, particularly in dissemination. The advice network is highly correlated with ASSP since it is completely relieved of significance when the ASSP variable is introduced. Hence it seems that the government's proposed policy to entrench the use of farming groups in the extension system is probably a more effective extension method. What is particularly important here is to understand that the community is showing signs that actors facilitate one another's farming development.

6.4.1.2 Plant Material Sharing

Planting material sharing is seen as a network of weak ties, as it is an exchange that requires an actor to forfeit something insubstantial. It was thought that this network would be insignificant, since advising on such a sophisticated innovation as a pheromone trap would need a close relationship, as the people would have to be willing to explain its application. These are people that a farmer has simply been referred to or has passed their field and extracted planting material. It would be unlikely for them to explain the innovation during this interaction. Interaction with this network is expected to be insignificant to learning.

For the first estimation, given in Table 24, the network effect is insignificant, regardless of the exclusion of the Acres variable. However, when we begin to introduce the extension variables the network effect becomes significant, and very much so when the Need RADA to Adopt variable is included. This shows a strong extension contact relationship. These variables are probably capturing the correlation with another variable, hence increasing the fit of the variable. The Need RADA to Adopt variable must be capturing a variable that reduces the significance of the network effect. When the ASSP variable is included with the extension variables the RADA contact retains its significance, but when Need RADA to Adopt is removed, the latter as well as the network effect becomes insignificant and ASSP remains significant, however minimally. It is likely that the need RADA contact variable is capturing confounding correlation with the ASSP variables as its removal causes both the variables that are strongly influenced by it, network effect and RADA contact, to become insignificant. However it also causes an increase in the ASSP estimate, so it seems that there is an omitted factor that is being controlled by this variable which is reducing the significance of those respective variables.

The market variables are again insignificant and do not have a strong influence on the network effect, except for the preference for information support. This latter variable caused the network effect to become slightly less significant, although the planting material attribute is still very significant. This is a similar result to the sweet potato advice network estimation. It is logical that this would be correlated to the planting material network as it concerns affinity with curiosity. Such people would probably have excellent planting materials, so they would be highly sought after. It is commonplace for information to spread about planting material quality, as everyone always wants the best crop, so if a farmer hears that another farmer had an exceptional yield they will seek out the source for the planting materials. This is particularly the case for sweet potato cuttings as it is hard to find high quality cuttings since the research area suffered from pest infestation (this actually has led to the development of a market for sweet potato cuttings).

The experience variables have an interesting relationship with the network effect. The results are the same for the planting experience and the time since being introduced to the innovation as they have no influence. However, when the Nursery Adoption and being Native to the Area are added, the network effect becomes insignificant; but this is only the combination of the two, as when they are added individually there is little difference in their influence. There must be a confounding relationship leading to the elimination of the network effects' significance. Nursery Adoption is a measure of curiosity, so this result is understandable. Originating from the community must capture community ties, as people

Table 24: Network Autoregressive Learning - Planting Material Sharing Network

Dependent = Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.036(.033)	-.016(.029)	-.026(.030)	-.042(.033)	-.051(.033)
Age	.002(.001)*	.001(.001)	.001(.001)	.003(.001)*	.003(.001)*
Acres	.003(.001)**	.001(.001)	.001(.001)	.001(.001)	.001(.001)
Household Size	.004(.006)	.007(.005)	.008(.005)	.007(.005)	.005(.005)
Export Buyers Known	.034(.009)***	.038(.008)***	.039(.009)***	.039(.009)***	.038(.009)***
Hospital Fees	.063(.035)*	.056(.031)*	.061(.033)*	.056(.033)*	.051(.034)
Children in Primary School	.042(.028)	.009(.025)	.009(.028)	.012(.028)	.001(.029)
Weevil is the Most Damaging Pest	-.042(.037)	-.016(.033)	-.018(.036)	-.021(.036)	-.033(.037)
Spatial AR	-.006(.007)	-.010(.006)*	-.010(.006)	-.010(.006)	-.014(.007)*
Planting Material Network AR Mean	.015(.011)	.029(.010)***	.032(.011)***	.029(.011)**	.018(.012)
Non-RADA Training	-	.033(.034)	.024(.037)	.025(.037)	.022(.038)
RADA Pest Advice Contact	-	.138(.037)***	.132(.039)***	.129(.032)***	.105(.042)**
Need RADA Support to Adopt	-	-.126(.033)***	-.132(.037)***	-.127(.037)***	-.114(.038)***
RADA Market Advice	-	-	-.022(.041)	-.018(.041)	-.020(.043)
Poor Market Access	-	-	-.041(.039)	-.045(.039)	-.029(.040)
Prefer Information Support	-	-	.008(.039)	.009(.039)	-.006(.040)
Secondary School	-	-	-	.048(.038)	.047(.039)
Years Planting SWP	-	-	-	-	-.002(.002)
Years Since Trap Introduction	-	-	-	-	.004(.007)
Nursery Adoption	-	-	-	-	.060(.043)
Native to Area	-	-	-	-	.071(.038)*
Observations	64	64	64	64	64
Adjusted R^2	.24	.43	.41	.42	.43

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

may only seek out those who are trustworthy. Consequently only high quality planting material is given. This may be reason people seeking planting material are drawn to those with strong ties to the community.

6.4.1.3 Market Sharing

This network is assumed to be the strongest, even more so than the RADA advice networks, since market is the primary driver. The first estimate, in Table 25, shows that it has the highest t-stat. The inclusion of the network variables increases the significance of the market variable, particularly with the inclusion of the Need RADA to Adopt variable. The same reasoning applies from the previous two networks regarding this variable. The attribute seems to be capturing the correlation that a variable has with the network effect. However, when the Need RADA to Adopt variable is excluded from the extension variables and ASSP is added, the network effect becomes insignificant. However, there is a great difference with the sweet potato advice network, and when ASSP is added after the extension variables, the network effect remains significant. This is interesting as it shows the independence of the network from the ASSP group. ASSP was meant not only as a training source, but also as a market source. This shows its particular strength. It is evident that advice networks are highly significant to ASSP membership, but this is not so with market sharing.

It was noted by traders in the qualitative study that the normal form of market sharing is word of mouth amongst traders and farmers. This provides support for informal sharing being the most significant market sharing source. Thus it is apparent that the market network is highly autonomous in that it does not stem from a formal source, but developed naturally. This suggests its likely resilience as it is self-supporting rather than being supported by an outside source. This increases its stock as a network for targeting. Networks that are reliant on other entities can easily dissipate once that entity has relinquished its support. It is best to focus on those not correlated with formal sources in policy application. The estimation is still significant when the market variables are added; however it is reduced due to the correlation with preference for information support. This is logical as those who are curious are going to have better market access because they are going to be more active farmers. Education is shown to have no significance on the variable. This continues support for the position that education is not as significant to learning as was once thought.

The experience variables are particularly relevant to the network effect. The results are similar to that of the plant sharing network as nursery adoption and being native to the research area are both influential to the network estimate. Their inclusion makes the network effect insignificant. However, planting experience and the time since being introduced to the trap are insignificant. Those who are more interested and have closer ties to the community are going to have more network access due to their superior crop quality and their ties to the community. In addition those who plant nurseries are more active farmers and may have more market information because they have strong interactions in the farming community. With respect to community ties, market sharing is an activity that can be sensitive as people are more apprehensive about giving away this information due

Table 25: Network Autoregressive Learning - Market Sharing Network

Dependent = Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.034(.033)	-.017(.029)	-.025(.030)	-.042(.032)	-.050(.032)
Age	.002(.001)*	.001(.001)	.002(.001)	.003(.001)*	.003(.001)*
Acres	.003(.001)**	.001(.001)	.001(.001)	.001(.001)	.001(.001)
Household Size	.003(.006)	.005(.005)	.006(.005)	.005(.005)	.004(.005)
Export Buyers Known	.034(.009)***	.037(.008)***	.037(.008)***	.037(.008)***	.037(.008)***
Hospital Fees	.054(.035)	.048(.031)	.049(.033)	.045(.032)	.045(.034)
Children in Primary School	.046(.027)*	.018(.024)	.023(.027)	.025(.027)	.009(.028)
Weevil is the Most Damaging Pest	-.034(.036)	-.004(.032)	-.000(.036)	-.004(.035)	-.022(.037)
Spatial AR	-.008(.007)	-.012(.006)*	-.012(.006)*	-.012(.006)*	-.016(.007)**
Market Sharing Network AR Mean	.019(.010)*	.027(.009)***	.029(.009)***	.028(.009)***	.020(.010)*
Non-RADA Training	-	.021(.034)	.008(.036)	.011(.036)	.011(.037)
RADA Pest Advice Contact	-	.127(.036)***	.119(.038)***	.116(.038)***	.097(.040)**
Need RADA Support to Adopt	-	-.121(.032)***	-.122(.036)***	-.118(.036)***	-.110(.036)***
RADA Market Advice	-	-	-.009(.041)	-.006(.041)	-.014(.042)
Poor Market Access	-	-	-.048(.039)	-.053(.039)	-.036(.040)
Prefer Information Support	-	-	-.001(.037)	.002(.037)	-.008(.038)
Secondary School	-	-	-	.054(.037)	.051(.038)
Years Planting SWP	-	-	-	-	-.001(.002)
Years Since Trap Introduction	-	-	-	-	.003(.007)
Nursery Adoption	-	-	-	-	.063(.041)
Native to Area	-	-	-	-	.069(.037)*
Observations	64	64	64	64	64
Adjusted R^2	.26	.44	.43	.44	.45

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

to competition. It is sensible to restrict sharing to those who are known in the community. Moreover, during the data collection, although many people noted community fractures, we came to understand that this was false.

The maintenance of the community identity is probably of more significance than people would have thought, as networks are correlated to having native ties. This network has shown itself to be very significant particularly since it is not influenced by the ASSP group. This seems to be the ideal network to target as it would disseminate without external assistance. The only disadvantage is that there are indications of clustering for people contacting RADA, based on the dyadic estimation. However, this is nullified by the result that the there is higher probability of link formation between confident farmers and those lacking in confidence, which is significant, particularly because this network is significant to learning. If those who are confident teach those who are less so and share markets with them, this is truly ideal because it combines factor and market development. Moreover, it gives a strong indication of altruistic sentiment in the community.

6.4.1.4 Tool Sharing[39]

The exchange of tools is akin to plant material sharing since it is viewed as being dominated by weak ties. There are those that place significance on it, but this sentiment was not prominent based on the qualitative study. It is thought that this network would not be particularly significant to the learning process. All estimations show that this network is insignificant. This confirms its insignificance for targeting.

6.4.1.5 Labour Sharing

An organization of this type requires high levels of trust, so the network effect is probably stronger. Moreover, this practice is mainly continued by more dedicated farmers and those who are members of ASSP (labour sharing groups were organized within this project). Hence, because of its association with ASSP it may be a significant learning influence. Its inclusion with the controls is insignificant, as given in Table 26. However, when the extension variables are added it becomes significant, particularly the Need RADA to Adopt variable. Another point is that the coefficient for the network effect is the highest for these estimations. Although the significance is slight, the influence that it has on learning is substantial. This may be due to the network's high trust level. The dyadic estimation showed that very high trust levels are exceptionally significant to this network and may lead to more thorough informal advising as well as application. Moreover, ASSP membership is likely to be prominent amongst these actors.

The experience variables are generally not influential, except for Prefer Information Support, which is correlated with the network effect. This probably relates to the connection to RADA, as many labour sharing group members were connected to ASSP and RADA. This variation would nullify the significance of the network effect.

[39] Results are in Table 8A in Appendix 3

Table 26: Network Autoregressive Learning - Labour Sharing Network

Dependent = Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.040(.034)	-.023(.030)	-.029(.032)	-.049(.034)	-.054(.032)*
Age	.002(.001)	.001(.001)	.001(.001)	.003(.001)*	.003(.001)
Acres	.003(.001)**	.001(.001)	.001(.001)	.001(.001)	.001(.001)
Household Size	.002(.006)	.004(.005)	.004(.005)	.003(.005)	.003(.005)
Export Buyers Known	.032(.009)***	.034(.008)***	.034(.009)***	.035(.009)***	.037(.008)***
Hospital Fees	.060(.037)	.053(.033)	.052(.035)	.047(.034)	.042(.035)
Children in Primary School	.044(.028)	.016(.026)	.021(.029)	.023(.029)	.003(.029)
Weevil is the Most Damaging Pest	-.037(.037)	-.009(.034)	-.002(.038)	-.007(.037)	-.025(.037)
Spatial AR	-.005(.007)	-.009(.006)	-.009(.007)	-.009(.007)	-.015(.007)**
Labour Sharing Network AR Mean	.022(.027)	.045(.025)*	.046(.027)*	.044(.026)*	.041(.029)
Non-RADA Training	-	.022(.036)	.012(.038)	.015(.038)	.013(.038)
RADA Pest Advice Contact	-	.118(.038)***	.118(.040)***	.116(.040)***	.094(.041)**
Need RADA Support to Adopt	-	-.121(.034)***	-.124(.039)***	-.120(.039)***	-.114(.038)***
RADA Market Advice	-	-	-.018(.043)	-.013(.043)	-.022(.043)
Poor Market Access	-	-	-.030(.041)	-.037(.040)	-.024(.039)
Prefer Information Support	-	-	-.020(.038)	-.015(.038)	-.023(.038)
Secondary School	-	-	-	.063(.039)	.053(.038)
Years Planting SWP	-	-	-	-	-.001(.002)
Years Since Trap Introduction	-	-	-	-	.004(.007)
Nursery Adoption	-	-	-	-	.064(.042)
Raised in Research Area	-	-	-	-	.095(.038)**
Observations	64	64	64	64	64
Adjusted R^2	.22	.38	.36	.38	.43

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

The education variable is shown to be insignificant, but the literacy variable is influential as its exclusion makes the network effect significant. Some of the dyadic estimations for labour sharing showed a strong significance for literacy influencing network formation so the result was expected. I am not sure why the literate would have a higher likelihood for joining this network.

This is the first network that is significantly influenced by planting experience. It may be because labour sharing group farmers are older and have more sweet potato planting experience. Age was seen as divisive in the dyadic estimation as well with it showing that older and younger farmers are less likely to forming links. Age has not been shown to be particularly relevant to learning but when it has been significant it has always been positive. As noted before, young farmers primarily plant illegal crops, so this indicates that it is mostly older farmers who are intrigued by new farming methods. Age is a very significant factor in this network as both the experience variables cause the network effect to become insignificant, illustrating once again that this is an institution for older farmers. This is not particularly due to young farmers having trust issues, but because they are involved in illegal farming, and it was deduced that there are even labour sharing groups for marijuana planters. Even the nursery variable, which is also correlated with age, makes the network effect insignificant. Due to this we can see just how important age is to this network. The final variable regarding community ties makes the labour sharing attribute strongly significant.

6.4.1.6 Family[40]

Throughout the literature, kinship or family is seen as pivotal in the diffusions process, as family is often at the centre of an actor's development. However, Jamaica has a westernized culture, so the individual is most people's main concern, not the general welfare of relatives. This is reinforced by farmers stating in the in-depth interviews that people prefer self-reliance over collective action. Moreover, land and other factors are not particularly dependent on familial resources, which means household economies function outside the spectrum of familial legacy. For this reason it was suspected that family would not be significant as it has been in the literature (Bandiera and Rasul, 2006; Van den Broeck and Dercon, 2011). The prevailing thought is that endowed resources as well as unbreakable trust and social support have a great influence on the success of a farmer, but this is not the case here. This is supported by the fact that none of the estimates are significant, illustrating that familial connections are irrelevant.

6.4.2 Adoption

Adoption differs from learning in that it is a one shot event rather than a behaviour acquired over time. Also, the network autoregressive term will be applied within a panel IV-2SLS model in order to control for endogeneity in the RADA contact variable. The same instrument as in the adoption chapter, innovation age insignificance, is used here.

[40] Results are in Tables 9A in Appendix 3

Sweet Potato Advice

It is evident from Table 27 that the adoption estimations are in stark contrast with the learning results. As the principal network it is not significant in any of the estimations. It is only once the year of planting sweet potato and SAR term are excluded that network effect becomes significant; however in all the successive formations of the adoption, it is not significant.

This indicates that the network may not be as influential to adoption as to learning. The networks are significant in the sense that they provide learning support for actors. However, only export market access, training contact and space are significant adoption influences, not one's reference group. This is indicative of the nature of the behavioural interaction. Adoption does not necessarily need substantial explanation and advising in order for the behaviour to be adopted. A farmer can adopt based on observation (this is probably related to spatial relationships). This is shown by the very significant SAR term. Moreover, farmers universally noted in the qualitative study that it is normal for farmers to form their adoption decision based on observation. Hence, they do not need social reinforcement such as learning.

Planting Material Sharing[41]

Again, the network effect is shown to be insignificant. This network shows a strong correlation with spatial influence and planting experience, as well as market access. This reaffirms the position that networks are primarily influential to learning, as it demands that someone take the time to carefully explain the activity. Moreover, that observability is very significant. Those who are near people that are adopting are strongly influenced by their behaviour. This contrasts with the learning estimation in which the spatial term is insignificant.

Market Sharing[42]

The same result occurs for this variable as it is shown that the network is insignificant and that the network is determined by space and planting experience.

Tool Sharing[43]

The same result occurs for this variable as it is shown that the network is insignificant and that the network is determined by space and planting experience.

[41] Results are in Table 10A in Appendix 3
[42] Results are in Table 11A in Appendix 3
[43] Results are in Table 12A in Appendix 3

Table 27: Network Autoregressive Adoption - Sweet Potato Advice Network[44]

Dependent = Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.850(.379)**	.834(.342)**	.660(.295)**	.715(.344)**	.581(.319)*	.551(.326)*
Household Size	.079(.058)	.102(.066)	.083(.057)	.085(.070)	.088(.067)	.132(.085)
Age	-.001(.015)	-.019(.014)	-.014(.016)	-.012(.018)	-.009(.017)	-.024(.025)
Acres	.014(.013)	.002(.032)	.001(.029)	.005(.028)	.004(.024)	.001(.029)
Hospital Fees	.341(.240)	.664(.350)*	.681(.295)**	.646(.379)*	.582(.348)*	.668(.332)**
Children in Primary School	-.250(.178)	-.464(.291)	-.451(.261)*	-.410(.277)	-.345(.278)	-.408(.289)
Export Buyers Known	.259(.090)***	.236(.136)*	.237(.128)*	.253(.145)*	.223(.126)*	.203(.136)
Years Planting SWP	-.023(.027)	-.025(.023)	-.012(.026)	-.015(.030)	-.021(.026)	-.021(.028)
SWP Advice Network AR Mean	.121(.100)	.036(.070)	.002(.069)	.001(.072)	-.022(.067)	-.043(.079)
Spatial AR	.104(.012)***	.072(.017)***	.076(.017)***	.077(.020)***	.085(.019)***	.081(.019)***
IV – RADA SWP Advice	-	.474(.204)**	.419(.184)**	.380(.235)	.279(.182)	.380(.227)*
Visit RADA Office	-	-.591(.341)*	-.437(.260)*	-.362(.366)	-.442(.277)	-.351(.323)
Friend Innovation Advice	-	.876(.504)*	.644(.412)	.619(.645)	.553(.501)	.959(.695)
Poor Market Access	-	-	-.810(.440)*	-.827(.483)*	-.533(.458)	-.456(.579)
RADA Market Advice	-	-	-.196(.411)	-.259(.429)	-.164(.386)	-.396(.461)
Microwave	-	-	-	-.383(.446)	-.090(.381)	-.180(.437)
Nursery Adoption	-	-	-	-	.540(.380)	.517(.403)
Prefer Information Support	-	-	-	-	-.966(.377)**	-.964(.393)**
Pest Scouting	-	-	-	-	-	-.485(.537)
Pest Barrier	-	-	-	-	-	-.172(.665)
Adopt to Reduce Pesticide	-	-	-	-	-	.627(.369)*
Observations	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

[44] Linear probability estimations with R^2 values are in Table 14A in Appendix 3

Table 28: Network Autoregressive Adoption - Family Network[45]

Dependent = Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.745(.368)**	.743(.310)**	.620(.297)**	.666(.323)**	.566(.285)**	.535(.316)*
Household Size	.060(.065)	.035(.054)	.033(.059)	.042(.066)	.051(.068)	.083(.069)
Age	-.004(.015)	-.017(.015)	-.012(.012)	-.011(.016)	-.006(.016)	-.018(.022)
Acres	.015(.013)	.005(.030)	.004(.028)	.006(.030)	.005(.028)	.002(.025)
Hospital Fees	.317(.237)	.639(.440)	.667(.314)**	.644(.325)**	.576(.354)	.634(.333)*
Children in Primary School	-.215(.177)	-.428(.364)	-.435(.282)	-.405(.286)	-.342(.275)	-.396(.251)
Export Buyers Known	.272(.088)***	.233(.139)*	.228(.122)*	.241(.122)**	.209(.146)	.188(.104)*
Years Planting SWP	-.014(.026)	-.022(.023)	-.014(.021)	-.015(.026)	-.023(.031)	-.025(.028)
Family Network AR Mean	.122(.191)	.449(.238)	.356(.223)	.302(.255)	.247(.242)	.359(.232)
Spatial AR	.104(.012)***	.074(.019)***	.076(.019)***	.077(.021)***	.085(.022)***	.082(.019)***
IV – RADA SWP Advice	-	.457(.238)*	.420(.221)*	.393(.210)*	.287(.160)*	.371(.200)*
Visit RADA Office	-	-.514(.331)	-.388(.331)	-.344(344)	-.433(.276)	-.293(.262)
Friend Innovation Advice	-	.835(.485)*	.632(.477)	.617(604)	.546(.474)	.893(.641)
Poor Market Access	-	-	-.722(.442)	-.752(.533)	-.432(.496)	-.369(.552)
RADA Market Advice	-	-	-.173(.373)	-.216(.380)	-.115(.376)	-.332(.553)
Microwave	-	-	-	-.271(.515)	.019(.499)	-.024(.416)
Nursery Adoption	-	-	-	-	.581(.501)	.533(.489)
Prefer Information Support	-	-	-	-	-.958(.439)**	-.864(.380)**
Pest Scouting	-	-	-	-	-	-.322(.441)
Pest Barrier	-	-	-	-	-	-.164(.655)
Adopt to Reduce Pesticide	-	-	-	-	-	.742(.378)*
Observations	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

[45] Linear probability estimations with R^2 values are in Table 15A in Appendix 3

Labour Sharing[46]

The same result occurs for this variable as it is shown that the network is insignificant and that the network is determined by space and planting experience.

Family

This is actually the only network that has a significant network effect. It is only the extension model estimation in Table 28 that indicates that one's familial reference group increases their likelihood of adoption. It is unsure why all other estimations would be insignificant.

6.5 Conclusion

The primary result is the difference in the network effects between the learning and adoption estimations. For the learning estimation, almost every network has an influence on learning whereas in adoption only one particular model was of significance. This confirms the position that learning requires exceptional support as opposed to adoption, which is primarily determined by space and extension contact. The reason is that the sophistication of the innovation requires that people have support from fellow farmers to assist in learning (Munshi, 2004). This contrasts with adoption, which simply requires one to acquire the innovation and necessitates far less effort than understanding its application and function.

This result on its own instigates interesting discussion as it shows not only the relevance of networks in the innovation transfer process, but also that they should be used strategically. They should be targeted towards behaviour that is of such depth that it requires a prolonged period of interaction to acquire it. This means that networks should not be targeted to influence simple changes in behaviour, such as the adoption of a seed or a pheromone trap, but rather towards understanding processes and factor application. By identifying the networks that are most suitable, one can use them as training sources to reinforce as well as disseminate information. This would help increase the efficacy of training and reduce the burden on the extension services. It can be said that due to the correlation of the ASSP group, the networks are not actually of significance, but this does not take into consideration that the presence of such a group is rare and in a community that does not have such support the networks would probably be prominent, particularly as networks were not significantly influenced by RADA advice contact. It is thought that networks should be sought for targeting. One network that should be highlighted is market sharing. This is the only network that was significant to learning with the inclusion of the ASSP variable. As a result it is the most appropriate network for targeting since it is the most robust.

[46] Results are in Table 13A in Appendix 3

The dyadic estimations indicated that network analysis can also be used to find divisions within the community, such as with the wealth and extension contact estimates that show fracturing which could stifle the diffusion process. By having a complex understanding of a community's social issues with regards to learning, adoption and networks, extension would be able to improve training efficacy by capitalizing on detailed social characteristics.

The final chapter is the conclusion. The results from the preceding chapters as well as the most significant findings are presented.

CHAPTER 7

Conclusion

This thesis presents an analysis of a primary agricultural innovation and social network dataset. This in itself is significant, as literature and data linking innovations and social networks are scarce. The thesis has reviewed the substantial literature on agricultural innovation and social effects, leading to a careful selection of relevant works. The data collection for network analysis is an exceptionally difficult task as many unique identification issues have to be accounted for. Addressing issues such as defining networks, boundaries and interaction direction is often impossible due to field constraints. I was fortunate in being able to collect appropriate data for this study.

The analysis of adoption, learning and network effects resulted in a number of interesting findings. The variable which stands out from the adoption and learning estimations was the number of export buyers known to the farmer. This is significant in that the purpose of the innovation is to increase crop quality as to increase access to the export market. This proved that the innovation was improving export market access. The data analysis provides a robust confirmation which indicates that the innovation is effective. Data collection issues often stifle the proving of an innovation's effectiveness, hence this is a significant finding.

The result is positive for the government because it can be assured that its efforts were successful, as manifest in the significant adoption rate. However, the innovation test scores were mediocre: this means that more effort needs to be made to improving knowledge levels. The results suggest that this could be achieved by a further understanding of diffusion through social networks. If reference groups and networks can be targeted, this will improve the probability of learning. Furthermore, if these social characteristics are capitalized on they can facilitate poverty reduction by improving research application.

A result just as important as the significance of networks is the indication of characteristics obstructing diffusion. In particular, there were results showing wealth and RADA pest contact clustering. These are causes for concern as the wealthy have more resource access and if they are not sharing, that indicates resource concentration. The latter is of even more concern as RADA is the most significant information source. Hence, if those contacting RADA do not share with those who are not, then diffusion is substantially stifled. This could be a reason why knowledge levels are so low. This concern was noted in Chapter 1. As network analysis can benefit from identifying not only positive relationships but also negative ones. It is possible that the identification of negative relationships could be even more helpful than identifying positive ones. If unfair practices can be minimized by identifying social bias, this could allow for the development of a training system which integrates mechanisms that protect against bias.

The most important findings are in the network effects, chapter 6. It was found that networks are significant to learning, but not to adoption, while space is strongly significant to adoption, even in the presence of networks. Learning requires a closer influence whereas adoption merely needs observation of the innovation. I drew from this that strength of ties, observability and behavioural reinforcement are the most significant issues. These phenomena are indicative of the hypotheses that I stated. The prediction was that learning would require network support, since learning needs reinforcement whereas adoption behaviour can be mimicked. This is also an example of non-learning interaction, as it concerns a contextual network influencing adoption rates.

The significance of networks to learning is particularly important to increasing diffusion. One of the problems that we noted in the first chapter was that training often fails in spurring one-to-many learning (Klerkx and Gildemacher, 2012). This is significant as a trained individual could lead to the teaching of numerous people. Such occurrences can substantially improve diffusion and adoption rates. Network analysis is an effective tool in deterring how to strategically train farmers to exploit one-to-many relationships.

As noted in Chapter 1, a common result within the empirical literature is that strength of ties and family networks are significant to adoption behaviour (Bandiera and Rasul, 2006; Van den Broeck and Dercon, 2011). This suggests that closeness and trust are central to livelihood decisions. However, we find that the strength of ties argument is contradicted by some of our results. The network not characterized by strong trust, market sharing, was the most significant to learning. This is an unexpected result as it provides support for the Granovetter weak ties theory wherein weak social connections are the cause of the behaviour. It was expected that farmers would primarily learn in networks that had strong ties and high levels of trust because of the innovation's sophistication. The premise was that farmers would reduce their information uncertainty by only seeking advice from those who they value substantially. This result means that farmers are not risk averse since they are using advice from low value links for their market strategy. It was noted by some in the qualitative study that farmers were generally not particularly cautious in planting. In addition, that trust in the learning source (market sharing links) was not particularly important. This brings forth many questions for further study, such as the convenience of talking with people or their market access.

Observability is when an actor observes an action independently without influence from a larger social entity such as a network. The strong influence of spatial effects and the minimal influence of network effects in my estimations in Chapter 6 show that people are strongly influenced by their ability to view other farmers' planting techniques. The neighbourhood effect is the main indicator for this phenomenon (Loury, 1977; Case, 1992). The result supports these positions as it is indeed the person's spatial neighbourhood that is influencing their decision. Their ability to view another's planting methods induces them to adopt. The social influence is not significant here as the network AR term is insignificant. Works such as Holloway et al. (2002), and Holloway and Lapar, (2007) show the significance of spatial neighbourhoods on farming decisions and how significant they can be to policymaking.

Before extension delves into the training of a technology, the best way to present it to farmers must be determined. A focus would need to be placed on the attributes that are significant to a farmer mimicking neighbour farmers. A cursory understanding of this may assist in improving the adoption rate, for example, strategically placing demonstration plots based on visibility and actor position.

Behavioural reinforcement involves continued support by others. In the case of innovation it is important for the training entity to understand not only the innovation, but how it will be received by the trainees. Moreover, the division of the innovation transfer process. When adopting a technology you simply need to choose whether you want to engage it or not. It does not need you to be competent in its application (although some may choose to be), it requires that there is sufficient cause for acquisition. These reasons can be superficial, such as status, or they can be specific to the innovation's purpose. However, what is significant is that competence is not required, so behavioural reinforcement would be insignificant. This was shown by the estimation, as almost none of the networks had any significance to adoption, but almost all of them did so in the learning estimations. This indicated the distinction between behaviour that can be induced by observability or social reinforcement. Trainers must have an understanding of this relationship in the transfer process. When they are designing a program for introducing an innovation they must differentiate which parts of the programme should be tailored with respect to behavioural reinforcement and develop specific methods for those aspects. This supports the idea provided by Le Gal, Dugue, Faure and Novak (2011), of 'Design Support' integrating famers into the innovation design process. This also lends itself to strategic intelligence presented by Smits (2002) as it regards developing empirically specific innovation design. These trainers would need to understand that after an innovation is adopted they have to create mechanisms which maintain consistent support to ensure that the farmers are as competent as possible. On the basis of these findings it seems clear that informal networks can assist in this process and improve the competence and retention of the innovation. These results reinforce the issues highlighted in Conley and Udry (2010) and Van den Broeck and Dercon (2011) during Chapter 1 in supporting the significance of networks to learning.

I would like to discuss a few points presented in the introduction chapter regarding the study's results and the literature. There are three primary works on agricultural innovation and networks in development: (Bandiera and Rasul, 2006); (Conley and Udry, 2010); and Van den Broeck and Dercon (2011). The first work had a few notable differences. The most notable one is that data was collected from multiple villages which means that the network data is disparate. However, village level fixed effects are used to control for location bias. Another difference was the absence of a direct question on advice. The sole questions asked were on how many family members, neighbours and friends adopted the innovation, but not on who provided advice or any other characteristics that would directly influence adoption. Here, the estimation is simply based on social pressure, but not on its strength. In general the focus of the study is different as it is interested in determining the significance of the number of network actors rather than general significance of the network. Aside from these differences there is one similarity, which is that more knowledgeable farmers are also shown to be less likely to share information here. Hence, they both show aspects of information clustering.

The next paper, Conley and Udry (2010) is special in that it has particularly sophisticated data. The authors were able to collect input and output data, and were able to estimate a farmer's innovation desire based on the innovation input and outcome results of fellow farmers. This was something that was sought but was not possible to do due to the limited resources, poor farmer recall and time. One aspect of the estimation that was particularly impressive was the robustness of checks on the network data by providing comparisons with alternative forms of interaction links. This provided a level of credibility that was not provided here.

The final study, Van den Broeck and Dercon (2011) is quite similar in many respects in terms of creating a census and employing direct advice questions as well as the use of dyadic estimation. However there are a couple differences that apply here, as well as to the previous works. In my study I was able to provide a comprehensive list of networks and no other study showed exceptional measures to account for all active networks. This is important for omitted variable bias concerns as one network could actually be capturing another, such as with spatial characteristics. In addition, no other study applied a network autoregressive model. This estimation is believed to be more suitable because it accounts for the social noise that determines relevance of links by valuing (strength of ties trust was a term used here) the significance of each link.

There are a few areas that would merit further research based on my findings. Data collection is the main concern. More research needs to be performed in understanding potential bias that can develop. For example, there is concern in this study that there is bias with regards to the high adoption rates in networks. This means that the respondents were possibly more likely to recall people that adopted. It is unsure what measures would need to be emplaced to prevent this bias. Other concerns regard estimation methods that take account of issues such as network self-selection, and the interaction of endogenous, exogenous and contextual network effects, as well as network simultaneity. These are only a few of the numerous issues that need to be addressed in this study area.

Policy application is particularly pertinent to this context as Jamaica has been seeking out ways to improve its training methods. One of the methods that has gained traction is the use of farming groups as community information and marketing centres. The purpose of this initiative is to increase farmer participation in the training process, reduce the strain on extension workers by providing a central distribution point as well as to improve dissemination by establishing community information hubs. The problem with these groups is that they are not resilient. For example, the farmer group in the research community quickly dissipated after external management support was withdraw. Due to this it is likely that a more decentralized approach such as network targeting would be more effective. By targeting natural dissemination channels, which farmers are more comfortable with, it is more probable that the dissemination channels would persist. Hence this should be a more effective method for improving training effectiveness.

The findings presented above are determined to be sufficient to warrant the efforts of this thesis as it provides support for the use of networks in extension. Although these efforts will require more substantial study to validate them, it is believed that they help in furthering research by giving reasons for future efforts.

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Appendices
Appendix 1: Adoption Tables

Table 1A: Descriptive Statistics - Variables

Variable	Mean	Std. Dev.	Min	Max
Age	51.859	11.652	27	84
Household Size	5.266	2.824	1	15
Literate	.494	.492	0	1
Acres	9.363	11.376	1	75
Export Buyers Known	1.688	1.972	0	10
Hospital Payments	.453	.504	0	1
Primary School Children	.539	.640	0	2.666
Years Planting Sweet Potato	7.156	6.473	1	33
RADA SWP Contact	.64	.427	0	1
Visit RADA Office	.520	.445	0	1
Friend Innovation Advice	.633	.470	0	1
Poor Market Access	.233	.412	0	1
RADA Market Advice	.246	.423	0	1
Microwave Ownership	.348	.439	0	1
Labour Sharing Member	.703	.460	0	1
Nursery Adoption	.232	.413	0	1
Prefers Information Support	.279	.441	0	1
Pest Scouting	.790	.403	0	1
Pest Barrier	.164	.364	0	1
Adopted to Reduce Pesticide	.581	.489	0	1

Notes: 384 Observations

Table 2A: Descriptive Statistics - Adoption

Variable	Mean		Std. Dev.		Min		Max	
	Adopt	No Adopt	Adopt	No Adopt	Adopt	No Adopt	Adopt	No Adopt
Age	51.127	53.578	10.309	14.523	27	30	76	84
Household Size	5.511	4.684	2.809	2.849	1	1	15	10
Literate	.511	.368	.505	.495	0	0	1	1
Acres	10.788	5.986	12.989	4.835	1	1	75	21
Export Buyers Known	1.930	1.111	2.071	1.629	0	0	10	5
Hospital Payments	.466	.421	.504	.507	0	0	1	1
Primary School Child.	.555	.5	.655	.621	0	0	2.666	2
Years Planting SWP	7.977	5.210	6.675	5.662	1	1	33	21
RADA SWP Contact	.725	.3	.425	.341	0	0	1	1
Visit RADA Office	.524	.508	.476	.372	0	0	1	1
Friend Innov. Advice	.583	.750	.487	.414	0	0	1	1
Poor Market Access	.171	.380	.364	.488	0	0	1	1
RADA Market Advice	.222	.263	.420	.452	0	0	1	1
Microwave Owner	.325	.401	.439	.448	0	0	1	1
Labour Sharing Member	.755	.578	.434	.507	0	0	1	1
Nursery Adoption	.266	.105	.447	.315	0	0	1	1
Prefers Info. Support	.151	.578	.343	.507	0	0	1	1
Pest Scouting	.835	.684	.365	.477	0	0	1	1
Pest Barrier	.166	.157	.364	.374	0	0	1	1
Adopt to Reduce Pest.	.622	.421	.490	.507	0	0	1	1

Notes: 384 Observations

Table 3A: Linear Probability IV-2SLS Panel Adoption Estimations

Variables	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Age	.000(.003)	-.006(.003)*	-.005(.003)	-.004(.003)	-.005(.003)	-.006(.004)
Literate	.119(.076)	.139(.071)*	.101(.073)	.128(.071)*	.075(.071)	.074(.073)
Household Size	.019(.12)*	.026(.012)**	.021(.012)*	.022(.011)*	.025(.011)**	.027(.012)**
Acres	.006(.003)**	.003(.003)	.004(.003)	.005(.003)*	.005(.003)*	.004(.003)
Export Buyers Known	.074(.018)***	.058(.018)***	.057(.018)***	.066(.017)***	.058(.017)***	.061(.018)***
Hospital Fees	.057(.051)	.124(.053)**	.124(.054)**	.112(.052)**	.106(.052)**	.103(.052)**
Primary School Children	-.057(.036)	-.128(.044)***	-.126(.044)***	-.106(.042)**	-.096(.043)**	-.103(.043)**
# Years Planting SWP	.007(.005)	.002(.005)	.006(.005)	.006(.005)	.004(.005)	.004(.005)
RADA SWP Contact IV *Innov Age*	-	1.034(.350)***	.953(.354)***	.857(.327)***	.800(.330)**	.725(.337)**
Visit RADA Office	-	-.178(.077)**	-.141(.078)*	-.114(.073)	-.133(.071)*	-.116(.075)
Friend Innov Advice	-	.259(.100)***	.289(.124)**	.273(.117)**	.295(.115)**	.304(.119)**
Poor Market Access	-	-	-.162(.084)*	-.179(.080)**	-.177(.084)**	-.202(.090)**
RADA Market Advice	-	-	.106(.101)	.075(.095)	.117(.095)	.101(.100)
Microwave	-	-	-	-.154(.067)**	-.117(.070)*	-.124(.071)*
Labour Sharing Past	-	-	-	-	.170(.075)**	.184(.077)**
Nursery Adoption	-	-	-	-	.031(.083)	.021(.088)
Information or Market Support	-	-	-	-	-.084(.077)	-.055(.083)
Pest Scouting	-	-	-	-	-	.017(.092)
Pest Barrier	-	-	-	-	-	.100(.115)
Adopt to Reduce	-	-	-	-	-	.072(.073)
Observations	384	384	384	384	384	384
R^2	.15	.20	.21	.22	.25	.26

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Appendix 2: Learning Tables

Table 4A: Descriptive Statistics - Non-Network Estimation Variables

Variable	Mean	Std. Dev.	Min	Max
RADA Sweet Potato Contact	.703	.460	0	1
Non RADA Training	.281	.453	0	1
RADA Field Visit	.72	.4	0	1
Need RADA to Adopt Innovations	.546	.501	0	1
Attended Sweet Potato Training	.5	.503	0	1
Information Support Preferred	.296	.460	0	1
Adopted to Reduce Pesticide	.562	.5	0	1
Innovation Age is Insignificant	.687	.467	0	1
Trap Innovator	.312	.404	0	1
Nursery Adoption	.218	.416	0	1
Weevil Most Invasive Pest	.703	.460	0	1
Export Buyers Known	1.872	1.894	0	10
Prefer RADA Market Advice	.234	.426	0	1
Sweet Potato is Primary Crop	.25	.436	0	1
Years Since RADA Contact	2.25	1.309	0	5
Years Since Innovation Introduction	4.158	2.489	0	10

Notes: 64 Observations

Table 5A: Descriptive Statistics - Non-Network Estimation Variables (Continued)

Variable	Mean	Std. Dev.	Min	Max
Past Labour Sharing Group Member	.703	.460	0	1
Years in Hounslow	40.555	17.319	3	84
Native to Area	.765	.426	0	1
Strong Community Ties	.359	.483	0	1
Literate	.468	.502	0	1
Primary School	.453	.501	0	1
Secondary School	.468	.503	0	1
Mountainside Primary School	.317	.465	0	1
Age	51.855	11.652	27	84
# of Years Farming	20.671	10.148	2	40
# of Years Planting Sweet Potato	7.156	6.473	1	33
Household Size	5.265	2.824	1	15
# of Primary School Children	.539	.640	0	2.666
Acres	9.308	11.394	1	75
Large Hospital Payments	.453	.501	0	1
Poor Market Perception	.233	.412	0	1
Satisfactory Market Perception	.183	.377	0	1
Very Good Market Perception	.199	.390	0	1

Notes: 64 Observations

Appendix 3: Network Tables

Table 6A: Descriptive Statistics Network Targeting Variables

Variable	Mean	Std. Dev.	Min	Max
Age	51.855	11.652	27	84
Literate	.468	.502	0	1
Acres	9.308	11.394	1	75
Export Buyers Known	1.872	1.894	0	10
Hospital Fees	.453	.501	0	1
Weevil Most Invasive Pest	.703	.460	0	1
ASSP Member	.180	.378	0	1
Water Users Association	.311	.455	0	1
Community Teacher #1	.196	.391	0	1
Community Teacher #2	.163	.364	0	1
Prefer Individual Support	.704	.448	0	1
Secondary School	.468	.503	0	1
Washing Machine	.189	.345	0	1
Pheromone Trap Experimentation	.090	.240	0	1
RADA Sweet Potato Contact	.703	.460	0	1
Non RADA Training	.281	.453	0	1
Need RADA to Adopt Innovations	.546	.501	0	1
Nursery Adoption	.218	.416	0	1
Information Support Preferred	.296	.460	0	1
Prefer RADA Market Advice	.234	.426	0	1
Poor Market Access	.233	.412	0	1
# of Years Planting Sweet Potato	7.156	6.473	1	33
Time in Research Area	40.555	17.319	3	84
Trap Knowledge Test Score	.357	.144	0	.769

Notes: 64 Observations

Table 7A: Descriptive Statistics - Trap Adoption and Networks

Variable	Mean	Std. Dev.
General Dyad	.090	.286
Sweet Potato Dyad	.052	.304
Plant Sharing Dyad	.089	.396
Market Sharing Dyad	.087	.391
Hired Labour Dyad	.017	.178
Labour Sharing Dyad	.023	.215
Family Dyad	.035	.247
Informal Insurance Dyad	.016	.170
Partners Dyad	.001	.062
Tool Sharing Dyad	.047	.295

Notes: 4096 Observations

Table 8A: Network Autoregressive Learning - Tool Sharing Network

Dependent=Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.038(.034)	-.019(.030)	-.026(.032)	-.046(.034)	-.053(.033)
Age	-.002(.001)*	.001(.001)	.002(.001)	.003(.001)**	.003(.001)*
Acres	.003(.001)**	.002(.001)*	.002(.001)	.001(.001)	.001(.001)
Household Size	.002(.006)	.004(.005)	.004(.005)	.003(.005)	.003(.005)
Export Buyers Known	.033(.009)***	.036(.008)***	.037(.009)***	.037(.009)***	.038(.009)***
Hospital Fees	.062(.036)*	.057(.033)*	.057(.034)*	.051(.034)	.047(.034)
Children in Primary School	.046(.028)	.019(.025)	.023(.029)	.025(.028)	.006(.029)
Weevil is the Most Damaging Pest	-.033(.038)	-.002(.034)	.002(.038)	-.001(.037)	-.022(.038)
Spatial AR	-.005(.007)	-.010(.006)	-.010(.007)	-.010(.007)	-.015(.007)**
Tool Sharing Network AR Mean	.020(.023)	.041(.021)*	.042(.022)*	.041(.022)*	.028(.023)
Non-RADA Training	-	.012(.035)	.003(.038)	.006(.037)	.009(.038)
RADA Pest Advice Contact	-	.124(.038)***	.124(.040)***	.121(.040)***	.097(.041)**
Need RADA Support to Adopt	-	-.118(.034)***	-.123(.039)***	-.119(.038)***	-.110(.038)***
RADA Market Advice	-	-	-.022(.043)	-.017(.042)	-.021(.043)
Poor Market Access	-	-	-.032(.040)	-.039(.040)	-.025(.040)
Prefer Information Support	-	-	-.016(.038)	-.011(.038)	-.019(.038)
Secondary School	-	-	-	.061(.039)	.053(.039)
# Years Planting SWP	-	-	-	-	-.001(.002)
# Years Since Trap Introduction	-	-	-	-	.005(.007)
Nursery Adoption	-	-	-	-	.066(.042)
Native to Area	-	-	-	-	.083(.037)**
Observations	64	64	64	64	64
Adjusted R^2	.22	.39	.37	.39	.43

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 9A: Network Autoregressive Learning - Family Network

Variables=Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Education	(5) Experience
Literate	-.053(.035)	-.041(.033)	-.042(.034)	-.057(.035)	-.067(.033)**
Age	.002(.001)	.001(.001)	.002(.001)	.003(.001)**	.003(.001)*
Acres	.003(.001)**	.002(.001)*	.002(.001)	.001(.001)	.001(.001)
Household Size	.003(.006)	.005(.005)	.004(.006)	.003(.006)	.003(.005)
Export Buyers Known	.032(.009)***	.033(.008)***	.033(.009)***	.035(.009)***	.034(.009)***
Hospital Fees	.065(.036)*	.063(.034)*	.059(.036)	.055(.035)	.048(.035)
Children in Primary School	.041(.029)	.017(.027)	.023(.031)	.028(.030)	-.000(.030)
Weevil is the Most Damaging Pest	-.040(.038)	-.016(.036)	-.006(.039)	-.007(.039)	-.039(.039)
Spatial AR	-.003(.007)	-.005(.006)	-.006(.007)	-.006(.007)	-.014(.007)*
Family Network AR Mean	-.025(.041)	-.021(.039)	-.019(.041)	.000(.042)	-.036(.044)
Non-RADA Training	-	.016(.036)	.009(.039)	.011(.039)	.016(.038)
RADA Pest Advice Contact	-	.117(.039)***	.124(.042)***	.117(.042)***	.096(.042)**
Need RADA Support to Adopt	-	-.098(.035)***	-.103(.040)**	-.104(.040)***	-.090(.038)**
RADA Market Advice	-	-	-.016(.045)	-.014(.044)	-.018(.044)
Poor Market Access	-	-	.017(.042)	-.028(.042)	-.007(.041)
Prefer Information Support	-	-	-.033(.039)	-.025(.039)	-.031(.038)
Secondary School	-	-	-	.064(.042)	.046(.041)
# Years Planting SWP	-	-	-	-	-.002(.002)
# Years Since Trap Introduction	-	-	-	-	.005(.007)
Nursery Adoption	-	-	-	-	.093(.046)**
Native to Area	-	-	-	-	.089(.038)**
Observations	64	64	64	64	64
Adjusted R^2	.22	.35	.32	.34	.41

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 10A: Network Autoregressive Adoption - Planting Material Sharing Network

Dependent=Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.897(.388)**	.907(.339)***	.731(.335)**	.772(.360)**	.641(.368)*	.617(.306)**
Household Size	.076(.059)	.099(.061)	.080(.058)	.081(.064)	.085(.058)	.130(.064)**
Age	-.001(.015)	-.017(.013)	-.012(.013)	-.010(.016)	-.007(.016)	-.023(.022)
Acres	.012(.013)	.000(.025)	.001(.028)	.004(.027)	.003(.014)	.001(.026)
Hospital Fees	.349(.241)	.660(.280)**	.675(.321)**	.642(.409)	.587(.268)**	.678(.327)**
Children in Primary School	-.256(.180)	-.465(.309)	-.465(.242)*	-.425(.290)	-.363(.202)*	-.429(.219)*
Export Buyers Known	.256(.090)***	.227(.137)*	.221(.108)**	.236(.134)*	.214(.085)**	.188(.140)
# Years Planting SWP	-.029(.029)	-.034(.025)	-.021(.026)	-.023(.025)	-.027(.030)	-.028(.031)
Planting Material Network AR Mean	.104(.072)	.081(.058)	.155(.096)	.074(.066)	.036(.074)	.034(.076)
Spatial AR	.104(.013)***	.073(.016)***	.075(.019)***	.077(.020)***	.085(.016)***	.080(.017)***
IV – RADA SWP Advice	-	.458(.199)**	.417(.173)**	.367(.174)**	.277(.164)*	.385(.187)**
Visit RADA Office	-	-.669(.283)**	-.515(.273)*	-.426(.296)	-.478(.345)	-.396(.336)
Friend Innovation Advice	-	.876(.533)*	.713(.434)*	.656(.466)	.575(.494)	1.000(.544)*
Poor Market Access	-	-	-.811(.569)	-.828(.529)	-.522(.421)	-.395(.529)
RADA Market Advice	-	-	-.074(.358)	-.151(.427)	-.101(.463)	-.323(.430)
Microwave	-	-	-	-.326(.362)	-.068(.342)	-.157(.430)
Nursery Adoption	-	-	-	-	.544(.427)	.529(.374)
Prefer Information Support	-	-	-	-	-.897(.399)**	-.914(.402)**
Pest Scouting	-	-	-	-	-	-.545(.593)
Pest Barrier	-	-	-	-	-	-.210(.641)
Adopt to Reduce Pesticide	-	-	-	-	-	.608(.369)*
Observations	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 11A: Network Autoregressive Adoption - Market Sharing Network

Dependent=Trap Test Score	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.836(.389)**	.820(.326)**	.670(.331)**	.723(.392)*	.557(.337)*	.520(.337)
Household Size	.075(.059)	.101(.076)	.080(.065)	.083(.065)	.093(.069)	.141(.078)*
Age	-.003(.015)	-.019(.017)	-.013(.015)	-.011(.015)	-.009(.016)	-.024(.023)
Acres	.012(.013)	.001(.029)	.001(.028)	.005(.029)	.005(.030)	.002(.030)
Hospital Fees	.343(.241)	.658(.358)*	.670(.370)*	.637(.358)*	.571(.298)*	.650(.368)*
Children in Primary School	-.253(.180)	-.465(.273)*	-.455(.295)	-.415(.283)	-.342(.301)	-.402(.313)
Export Buyers Known	.260(.091)***	.240(.149)	.231(.128)*	.249(.150)*	.230(.130)*	.213(.139)
# Years Planting SWP	-.021(.028)	-.025(.027)	-.014(.024)	-.017(.026)	-.021(.034)	-.021(.030)
Market Network AR Mean	.051(.065)	.014(.061)	.021(.066)	.017(.069)	-.027(.077)	-.044(.068)
Spatial AR	.104(.013)***	.073(.018)***	.076(.018)***	.077(.020)***	.085(.019)***	.081(.021)***
IV – RADA SWP Advice	-	.468(.203)**	.407(.215)*	.369(.220)*	.280(.189)	.380(.222)*
Visit RADA Office	-	-.637(.330)*	-.482(.315)	-.400(.339)	-.415(.293)	-.299(.308)
Friend Innovation Advice	-	.885(.568)	.648(.514)	.621(.477)	.553(.549)	.954(.624)
Poor Market Access	-	-	-.807(.514)	-.824(.511)	-.495(.507)	-.395(.598)
RADA Market Advice	-	-	-.153(.409)	-.223(.397)	-.166(.470)	-.397(.542)
Microwave	-	-	-	-.383(.443)	-.094(.399)	-.187(.419)
Nursery Adoption	-	-	-	-	.542(.401)	.512(.466)
Prefer Information Support	-	-	-	-	-.994(.397)**	-1.001(.456)**
Pest Scouting	-	-	-	-	-	-.470(.502)
Pest Barrier	-	-	-	-	-	-.160(.633)
Adopt to Reduce Pesticide	-	-	-	-	-	.642(.417)
Observation	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 12A: Network Autoregressive Adoption - Tool Sharing Network

Dependent=Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.781(.380)**	.827(.407)**	.685(.315)**	.741(.371)**	.598(.292)**	.602(.357)*
Household Size	.075(.0602)	.098(.065)	.077(.071)	.080(.069)	.092(.068)	.133(.071)*
Age	-.004(.015)	-.019(.015)	-.012(.018)	-.010(.014)	-.008(.017)	-.022(.023)
Acres	.013(.013)	.001(.027)	.001(.027)	.005(.031)	.005(.022)	.002(.028)
Hospital Fees	.334(.240)	.648(.287)**	.663(.334)*	.630(.337)*	.568(.311)*	.659(.355)*
Children in Primary School	-.239(.179)	-.453(.234)*	-.444(.294)	-.403(.306)	-.343(.249)	-.411(.261)
Export Buyers Known	.274(.089)***	.242(.127)*	.236(.122)*	.252(.128)*	.219(.127)*	.195(.111)*
# Years Planting SWP	-.016(.027)	-.024(.025)	-.014(.022)	-.016(.025)	-.024(.028)	-.026(.030)
Tool Sharing Network AR Mean	.037(.111)	.032(.138)	.043(.157)	.037(.140)	-.018(.106)	-.001(.142)
Spatial AR	.105(.013)***	.073(.019)***	.077(.016)***	.078(.018)***	.085(.018)***	.081(.018)***
IV – RADA SWP Advice	-	.457(.164)***	.399(.230)*	.362(.205)*	.280(.182)	.383(.192)**
Visit RADA Office	-	-.646(.322)**	-.496(.327)	-.416(.283)	-.436(.316)	-.375(.383)
Friend Innovation Advice	-	.877(.435)**	.628(.548)	.606(.560)	.563(.529)	.970(.586)*
Poor Market Access	-	-	-.811(.476)*	-.826(.502)*	-.512(.498)	-.411(.591)
RADA Market Advice	-	-	-.179(.425)	-.241(.390)	-.136(.356)	-.343(.495)
Microwave	-	-	-	-.381(.433)	-.097(.449)	-.185(.420)
Nursery Adoption	-	-	-	-	.527(.383)	.512(.441)
Prefer Information Support	-	-	-	-	-.960(.439)**	-.941(.471)**
Pest Scouting	-	-	-	-	-	-.498(.437)
Pest Barrier	-	-	-	-	-	-.181(.691)
Adopt to Reduce Pesticide	-	-	-	-	-	.608(.401)
Observations	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 13A: Network Autoregressive Adoption - Labour Sharing Network

Dependent=Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.795(377)**	.834(.362)**	.682(.259)***	.742(.351)**	.625(.329)*	.614(.407)
Household Size	.072(.059)	.100(.077)	.083(.066)	.084(.066)	.088(.081)	.133(.062)**
Age	-.003(.015)	-.018(.018)	-.013(.014)	-.011(.015)	-.007(.016)	-.022(.019)
Acres	.012(.013)	.002(.028)	.001(.023)	.005(.026)	.004(.028)	.001(.025)
Hospital Fees	.354(.242)	.633(.349)*	.677(.338)**	.643(.294)**	.582(.353)*	.681(.426)
Children in Primary School	-.250(.179)	-.442(.292)	-.456(.288)	-.413(.268)	-.354(.306)	-.420(.271)
Export Buyers Known	.269(.090)***	.251(.167)	.240(.108)**	.256(.135)*	.223(.138)	.196(.126)
# Years Planting SWP	-.017(.027)	-.023(.036)	-.013(.020)	-.016(.025)	-.024(.026)	-.025(.029)
Labour Sharing Network AR Mean	.135(.155)	.028(.229)	.021(.174)	.032(.180)	.013(.235)	.026(.212)
Spatial AR	.105(.013)***	.076(.019)***	.076(.021)***	.077(.019)***	.085(.020)***	.081(.019)***
IV – RADA SWP Advice	-	.420(.248)*	.411(.217)*	.369(.165)**	.276(.178)	.387(.240)
Visit RADA Office	-	-.632(.316)**	-.474(.297)	-.402(.276)	-.470(.290)	-.396(.298)
Friend Innovation Advice	-	.833(.633)	.661(.434)	.638(.413)	.566(.472)	1.000(.528)*
Poor Market Access	-	-	-.808(.448)*	-.826(.565)	-.513(.511)	-.389(.589)
RADA Market Advice	-	-	-.160(.374)	-.215(.386)	-.120(.350)	-.325(.475)
Microwave	-	-	-	-.389(.404)	-.091(.426)	-.175(.494)
Nursery Adoption	-	-	-	-	.546(.441)	.529(.482)
Prefer Information Support	-	-	-	-	-.935(.441)**	-.936(.383)**
Pest Scouting	-	-	-	-	-	-.532(.484)
Pest Barrier	-	-	-	-	-	-.244(.626)
Adopt to Reduce Pesticide	-	-	-	-	-	.621(.449)
Observations	384	384	384	384	384	384

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Table 14A: Linear Probability Network Autoregressive Adoption - Sweet Potato Advice Network

Dependent = Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.153(.070)**	.127(.068)*	.092(.071)	.111(.068)	.107(.067)	.097(.069)
Household Size	.016(.011)	.025(.011)**	.019(.011)*	.020(.011)*	.018(.011)*	.022(.011)*
Age	-.001(.002)	-.007(.003)*	-.005(.003)	-.004(.003)	-.003(.003)	-.005(.003)
Acres	.004(.002)	.003(.002)	.003(.002)	.004(.002)	.003(.002)	.003(.002)
Hospital Fees	.057(.043)	.116(.049)**	.117(.049)**	.108(.047)**	.101(.047)**	.106(.048)**
Children in Primary School	-.056(.031)*	-.122(.042)***	-.117(.042)***	-.105(.040)***	-.092(.040)**	-.098(.040)**
Export Buyers Known	.051(.017)***	.052(.016)***	.051(.016)***	.056(.016)***	.053(.016)***	.051(.016)***
Years Planting SWP	-.005(.005)	-.002(.005)	.000(.005)	.000(.005)	-.002(.005)	-.001(.005)
SWP Advice Network AR Mean	.020(.015)	-.014(.020)	-.015(.020)	-.015(.019)	-.015(.019)	-.020(.019)
Spatial AR	.022(.001)***	.014(.003)***	.015(.003)***	.015(.003)***	.016(.003)***	.016(.003)***
IV – RADA SWP Advice	-	.885(.376)**	.777(.366)**	.701(.338)**	.589(.336)*	.659(.326)**
Visit RADA Office	-	-.163(.073)**	-.124(.072)*	-.104(.069)	-.114(.068)*	-.101(.072)
Friend Innovation Advice	-	.237(.104)**	.236(.122)*	.223(.116)*	.198(.113)*	.229(.116)**
Poor Market Access	-	-	-.168(.081)**	-.180(.079)**	-.127(.081)	-.120(.087)
RADA Market Advice	-	-	.056(.092)	.033(.088)	.029(.088)	.008(.094)
Microwave	-	-	-	-.108(.064)*	-.064(.067)	-.065(.068)
Nursery Adoption	-	-	-	-	.104(.078)	.101(.082)
Prefer Information Support	-	-	-	-	-.113(.068)	-.097(.075)
Pest Scouting	-	-	-	-	-	-.019(.088)
Pest Barrier	-	-	-	-	-	-.080(.095)
Adopt to Reduce Pesticide	-	-	-	-	-	.057(.070)
Observations	384	384	384	384	384	384
R^2	.40	.43	.43	.44	.45	.45

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Tab le 15A: Linear Probability Network Autoregressive Adoption - Family Network

Dependent = Trap Adoption	(1) Controls	(2) Extension	(3) Market	(4) Welfare	(5) Risk	(6) Innovator
Literate	.133(.069)*	.139(.066)**	.109(.067)	.124(.066)*	.122(.066)*	.118(.067)*
Household Size	.013(.012)	.013(.012)	.010(.012)	.012(.012)	.010(.012)	.013(.012)
Age	-.002(.002)	-.005(.003)*	-.004(.003)	-.004(.003)	-.002(.003)	-.003(.003)
Acres	.004(.002)	.003(.002)	.003(.002)	.004(.002)	.003(.002)	.003(.002)
Hospital Fees	.064(.045)	.108(.047)**	.109(.047)**	.104(.046)**	.097(.047)**	.099(.047)**
Children in Primary School	-.062(.034)*	-.112(.040)***	-.110(.040)***	-.101(.039)**	-.090(.040)**	-.094(.040)**
Export Buyers Known	.052(.017)***	.048(.016)***	.047(.016)***	.052(.016)***	.048(.016)***	.046(.016)***
Years Planting SWP	-.004(.005)	-.003(.005)	-.001(.005)	-.001(.005)	-.003(.005)	-.003(.005)
SWP Advice Network AR Mean	.172(.207)	.079(.043)*	.069(.043)	.053(.042)	.053(.042)	.061(.043)
Spatial AR	.021(.002)***	.014(.003)***	.015(.003)***	.015(.003)***	.016(.003)***	.016(.003)***
IV – RADA SWP Advice	-	.840(.351)**	.762(.359)**	.706(.341)**	.600(.345)*	.640(.322)**
Visit RADA Office	-	-.140(.070)**	-.110(.071)	-.099(.069)	-.110(.067)	-.091(.071)
Friend Innovation Advice	-	.213(.095)**	.230(.121)*	.221(.117)*	.194(.113)*	.217(.114)*
Poor Market Access	-	-	-.139(.078)*	-.151(.076)**	-.098(.079)	-.090(.084)
RADA Market Advice	-	-	.073(.097)	.055(.093)	.047(.091)	.029(.096)
Microwave	-	-	-	-.082(.063)	-.037(.066)	-.035(.068)
Nursery Adoption	-	-	-	-	.115(.080)	.108(.083)
Prefer Information Support	-	-	-	-	-.099(.071)	-.075(.078)
Pest Scouting	-	-	-	-	-	-.000(.089)
Pest Barrier	-	-	-	-	-	-.068(.095)
Adopt to Reduce Pesticide	-	-	-	-	-	.064(.070)
Observations	384	384	384	384	384	384
R^2	.40	.42	.43	.44	.45	.45

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%

Appendix 4: Variable Descriptions

Table 16A: Adoption Estimation Variable Description Table

Variable Name	Questionnaire Question 1. = *Preliminary* 2. = *Main*	Variable Description
Age	1. What is your age?	Age of respondent
Literate	None	A question was not asked. The respondent was asked to read the network roster and if they could I marked them as literate
Household Size	2. From 2003-2008 how many people lived in your house? Count Adults and Children	How many people lived in the respondent's household during the period of interest
Acres	2. For each respective piece of land you held during 2003-2008, what is the size of the plot in acres and/or squares?	How much land the respondent held during the period of interest
Export Buyers Known	2. From 2003-2008 how many buyers do you know of that sold solely to the export market?	Out of the number of buyers that a respondent knows of or has sold to this is the number of buyers that sell exclusively to the export market
Hospital Fees	2. From 2003-2008 did you pay any hospital bills over JMD 10,000? If yes, How many people? Please note the number of people for each respective year	The farmers recall the number of people that they have paid hospital bills for that are over JMD 10,000 for each year of the period of interest
Primary School Children	2. From 2003-2008 did you support any children? Please note how many and their respective level of schooling for each year.	The farmers recall the number of children that they have supported and their respective level of schooling. The number of primary school children were extracted from this.
# of Years Planting Sweet Potato	2. What was the first year that you started planting sweet potato for market? From then until now how many years have you planted sweet potato for market?	This is the total number of years that a farmer has planted sweet potato for market.
RADA SWP Contact IV - *Innov Age*	2. Have you ever spoken to a RADA officer about sweet potato IPM or pest control? If so, how many times and when? Please respectively note the number of times for 2003-2008. *Instrument: Which do you prefer, traditional planting methods, or the most effective methods regardless of tradition?*	This is the instrument for the RADA Sweet Potato pest advice contact variable. The variable regards whether not the respondent has conversed with a RADA officer about sweet potato IPM or pest control during the respective years of the period of interest. The instrument captures whether the farmer is concerned with the age of innovations.
Visit RADA Office	2. From 2003-2008 did you ever visit a RADA office for advice? Please note the	Accounts for when farmers visited a RADA office during the period of interest.

	respective years.	
Friend Innov Advice	2. Who would you prefer to contact for technical advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for innovation advice
Poor Market Access	2. From 2003-2008 how would you rate your sweet potato market access? Please note if it was very good, good, okay, not so good or poor.	This is simply those farmers that note having poor market access during the period of interest
RADA Market Advice	2. Who would you prefer to contact for market advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for market advice
Microwave	2. Note if you owned a microwave for the respective years of 2003-2008	Microwave ownership for each year of the period of interest
Labour Sharing Past	1. Have you ever been in a Day for Day group?	Accounts for whether a respondent has ever participated in a labour sharing group
Nursery Adoption	2. Have you ever planted a slip nursery?	Makes notes of whether a farmer has planted a cuttings nursery
Information or Market Support	2. The purpose of this set of techniques that I just asked about is to increase the percentage of exportable sweet potato. Which is your belief with respect to them? That you need more information about these techniques or that you understand the techniques and need more export market support	Records whether the farmer wants additional information or export market support for IPM.
Pest Scouting	2. Did you do pest scouting? If yes, please note the plantings that it was performed on during 2003-2008	Captures when pest scouting was performed plantings during the period of interest
Pest Barrier	2. Did you plant pest barriers? If yes, please note the plantings that it was applied to during 2003-2008	Captures when pest barriers were applied for plantings during the period of interest
Adopt to Reduce Pesticide	2. Do you use these techniques to reduce your reliance on chemicals for managing pests?	Notes whether farmers understand the purpose of IPM to reduce pesticide use

Table 17A: Learning Estimation Variable Description Table

Variable Name	Questionnaire Question 1. = *Preliminary* 2. = *Main*	Variable Description
Age	1. What is your age?	Age of respondent
Literate	None	A question was not asked. The respondent was asked to read the network roster and if they could I marked them as literate
Household Size	2. From 2003-2008 how many people lived in your house? Count Adults and Children	How many people lived in the respondent's household during the period of interest
Acres	2. For each respective piece of land you held during 2003-2008, what is the size of the plot in acres and/or squares?	How much land the respondent held during the period of interest
Export Buyers Known	2. From 2003-2008 how many buyers do you know of that sold solely to the export market?	Out of the number of buyers that a respondent knows of or has sold to this is the number of buyers that sell exclusively to the export market
Innov. Age is Insignificant	2. Which do you prefer, traditional planting methods, or the most effective methods regardless of tradition?	The instrument captures whether the farmer is concerned with the age of innovations.
RADA SWP Contact	2. Have you ever spoken to a RADA officer about sweet potato IPM or pest control? If so, how many times and when? Please respectively note the number of times for 2003-2008.	The variable regards whether not the respondent has conversed with a RADA officer about sweet potato IPM or pest control during the respective years of the period of interest.
Training Attendance	2. From 2003-2008 did you ever attend a sweet potato pest control training?	Accounts for attending a sweet potato pest control training during the period of interest
# of Trainings Attended	2. From 2003-2008 did you ever attend a sweet potato pest control training?	Accounts for number of times the person attended a sweet potato pest control training
Non-RADA Training	2. Have any other non-farmers given you information about sweet potato integrated management?	This represents any other formal training sources that farmers received sweet potato IPM advice from
RADA Field Visit	2. From 2003-2008 has a RADA officer ever visited your field?	Notes whether a farmer has had a field visited by a RADA officer
Need RADA to Adopt Innov	2. In order for you to adopt a technology do you need a RADA officer to explain it to you?	This variable captures if in general the respondent needs RADA assistance in order to adopt an innovation
Need Info More than Market	2. The purpose of this set of techniques that I just asked about is to increase the percentage of exportable sweet potato. Which is your belief with respect to them? That you need more information about	Records whether the farmer wants information or export market support for IPM.

	these techniques or that you understand the techniques and need more export market support	
# Years Planting SWP	2. What was the first year that you started planting sweet potato for market? From then until now how many years have you planted sweet potato for market?	This is the total number of years that a farmer has planted sweet potato for market.
Trap Innovator	2. Do you use and innovation for the better use of traps?	Records if the farmer innovated on the trap in anyway?
Weevil Most Invasive Pest	1. From most to least damaging, name the pests that have caused damage to your sweet potato since you first planted it	All people that answered with the weevil as the most damaging pest since they started planting
Nursery Adoption	2. Have you ever planted a slip nursery?	Makes notes of whether a farmer has planted a cuttings nursery
RADA Market Advice	2. Who would you prefer to contact for market advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for market advice
Market Perception Poor	2. From 2003-2008 how would you rate your sweet potato market access? Please note if it was very good, good, okay, not so good or poor.	This is simply those farmers that note having poor market access during the period of interest
Market Perception Satisfactory	2. From 2003-2008 how would you rate your sweet potato market access? Please note if it was very good, good, okay, not so good or poor.	This is simply those farmers that note having satisfactory market access during the period of interest
Market Perception Very Good	2. From 2003-2008 how would you rate your sweet potato market access? Please note if it was very good, good, okay, not so good or poor.	This is simply those farmers that note having very good market access during the period of interest
Hospital Fees	2. From 2003-2008 did you pay any hospital bills over JMD 10,000? If yes, How many people? Please note the number of people for each respective year	The farmers recall the number of people that they have paid hospital bills for that are over JMD 10,000 for each year of the period of interest
Primary Education	1. Check off the level of school that has been completed. Primary, Secondary, Community College or University	This simply shows that the highest level of school of the respondent is primary school
Mountainside Primary School	1. Please give the name of the schools that you have attended	This captures whether the farmer attended Mountainside Primary School
Secondary Education	1. Please give the name of the schools that you have attended	This captures whether the farmer attended Secondary School
# Years Living in Hounslow	2. How many years have you farmed or lived in Hounslow?	This regards the number of years that the respondent has had a significant presence in

		the community
# Years Farming	2. For how many years have you been independently farming for the market?	Accounts for how long the person has been engaged in farming as their livelihood
# Years Since Intro. to Trap	2. Have you heard about the pheromone trap technique? *The difference is taken of the year of the survey and the answer*	Notes how long the respondent has known about the pheromone trap
# Years Since RADA Contact	2. When was the last time that you spoke to a RADA officer? *The difference is taken of the year of the survey and the answer*	Notes the number of years since the farmer has last contacted RADA
Native to Area	2. Were you raised in Hounslow	Represents the farmer being native to the research area
Numerous Relatives	2. How many relatives do you have in Hounslow? Do you have enough to satisfy number 13?	This means that the farmer has over 60 relatives in the area or so many that they cannot be counted
Past Labour Sharing Group Member	1. Have you ever been in a Day for Day group?	Accounts for whether a respondent has ever participated in a labour sharing group

Table 18A: Network Estimation Variable Description Table

Variable Name	Questionnaire Question 1. = *Preliminary* 2. = *Main*	Variable Description
Age	1. What is your age?	Age of respondent
Literate	None	A question was not asked. The respondent was asked to read the network roster and if they could I marked them as literate
Acres	2. For each respective piece of land you held during 2003-2008, what is the size of the plot in acres and/or squares?	How much land the respondent held during the period of interest
Export Buyers Known	2. From 2003-2008 how many buyers do you know of that sold solely to the export market?	Out of the number of buyers that a respondent knows of or has sold to this is the number of buyers that sell exclusively to the export market
Hospital Fees	2. From 2003-2008 did you pay any hospital bills over JMD 10,000? If yes, How many people? Please note the number of people for each respective year	The farmers recall the number of people that they have paid hospital bills for that are over JMD 10,000 for each year of the period of interest
Weevil Most Invasive Pest	1. From most to least damaging, name the pests that have caused damage to your sweet potato since you first planted it	All people that answered with the weevil as the most damaging pest since they started planting
ASSP	2. Give the names of all farming and water groups that you have been in from 2003-2008	Represents a farmer's membership of ASSP from 2003-2008
WUA	2. Give the names of all farming and water groups that you have been in from 2003-2008	Represents a farmer's membership of WUA from 2003-2008
Community Teacher 1	2. Are there any people on the list that you request advice from, but you don't provide advice for?	This is 1 of 2 farmers who were most popularly viewed as farming teachers in the community
Community Teacher 2	2. Are there any people on the list that you request advice from, but you don't provide advice for?	This is 1 of 2 farmers who were most popularly viewed as farming teachers in the community
Prefers Indiv. Farm Support	2. If you were able to get the benefits of the group yourself, would you prefer doing it yourself rather than joining the group?	The respondent chooses to receive individual farming support if it is available (*1=Yes)* as opposed to group support
Secondary Education	1. Please give the name of the schools that you have attended	This captures whether the farmer attended Secondary School
Washing Machine	2. In the durables section the item 'Washing' represents washing machine ownership	Washing machine ownership
Trap Experimentation	2. Did you experiment with this before somebody trained you?	Notes if someone experimented with a technique without training
RADA SWP Contact	2. Have you ever spoken to a RADA officer about sweet potato IPM or pest control? If so, how	The variable regards whether not the respondent has conversed with a RADA officer about sweet

	many times and when? Please respectively note the number of times for 2003-2008.	potato IPM or pest control during the respective years of the period of interest.
Non-RADA Training	2. Have any other non-farmers given you information about sweet potato integrated management?	This represents any other formal training sources that farmers received sweet potato IPM advice from
Need RADA to Adopt	2. In order for you to adopt a technology do you need a RADA officer to explain it to you?	This variable captures if in general the respondent needs RADA assistance in order to adopt an innovation
Nursery Adoption	2. Have you ever planted a slip nursery?	Makes notes of whether a farmer has planted a cuttings nursery
Prefers Information Support	2. The purpose of this set of techniques that I just asked about is to increase the percentage of exportable sweet potato. Which is your belief with respect to them? That you need more information about these techniques or that you understand the techniques and need more export market support	Records whether the farmer wants additional information or export market support for IPM.
RADA Market Advice	2. Who would you prefer to contact for market advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for market advice
Poor Market Access	2. From 2003-2008 how would you rate your sweet potato market access? Please note if it was very good, good, okay, not so good or poor.	This is simply those farmers that note having poor market access during the period of interest
Years Planting SWP	2. What was the first year that you started planting sweet potato for market? From then until now how many years have you planted sweet potato for market?	This is the total number of years that a farmer has planted sweet potato for market.
Time in Research Area	2. How many years have you farmed or lived in Hounslow?	This regards the number of years that the respondent has had a significant presence in the community
Trap Test Score	2. *This is an index of the trap test score questions*	The score of the pheromone trap questions
Same Home District	2. Location of this person: Home	The home administrative district
Same Gender	2. Gender: 1=Male, 0=Female	Gender of the farmer
Very High Trust	2. On a scale from 1-5 (5 being the highest, trusting them with managing your money and 1 being you would no trust them to help you cross the road) how much do you trust this person? *The highest level of trust is chosen*	The highest level of trust with their network link
Daily Interaction	2. From 2003-2008, how often have you spoken with this person? *Daily interaction is*	Daily interaction with network link

	chosen	
Years Friends	2. For how many years have you been good friends or 'bredren' with this person?	The number of years that a person has been friends with the network link
Spatial AR	2. GIS Coordinates for Land	The GIS distance between sweet potato plots for every farmer
SWP Advice Network AR Mean	2. Combination of the Very High Trust and Trap Test Score variables for reference groups of each respondent	The weighted social distance combined with the average reference group pheromone trap test score for network links
Planting Material Network AR Mean	2. Combination of the Very High Trust and Trap Test Score variables for reference groups of each respondent	The weighted social distance combined with the average reference group pheromone trap test score for network links
Market Sharing Network AR Mean	2. Combination of the Very High Trust and Trap Test Score variables for reference groups of each respondent	The weighted social distance combined with the average reference group pheromone trap test score for network links
Labour Sharing Network AR Mean	2. Combination of the Very High Trust and Trap Test Score variables for reference groups of each respondent	The weighted social distance combined with the average reference group pheromone trap test score for network links
Family Network AR Mean	2. Combination of the Very High Trust and Trap Test Score variables for reference groups of each respondent	The weighted social distance combined with the average reference group pheromone trap test score for network links
IV - RADA SWP Advice	2. Have you ever spoken to a RADA officer about sweet potato IPM or pest control? If so, how many times and when? Please respectively note the number of times for 2003-2008. *Instrument: Which do you prefer, traditional planting methods, or the most effective methods regardless of tradition?*	This is the instrument for the RADA Sweet Potato pest advice contact variable. The variable regards whether not the respondent has conversed with a RADA officer about sweet potato IPM or pest control during the respective years of the period of interest. The instrument captures whether the farmer is concerned with the age of innovations.
Visit RADA Office	2. From 2003-2008 did you ever visit a RADA office for advice? Please note the respective years.	Accounts for when farmers visited a RADA office during the period of interest.
Household Size	2. From 2003-2008 how many people lived in your house? Count Adults and Children	How many people lived in the respondent's household during the period of interest
Children in Primary School	2. From 2003-2008 did you support any children? Please note how many and their respective level of schooling for each year.	The farmers recall the number of children that they have supported and their respective level of schooling. The number of primary school children were extracted from this.
Weevil is the Most Damaging Pest	1. From most to least damaging, name the pests that have caused damage to your sweet potato since you first planted it	All people that answered with the weevil as the most damaging pest since they started planting
Years Since Trap Introduction	2. Who would you prefer to contact for technical advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for innovation advice

Native to Area	2. Were you raised in Hounslow	Represents the farmer being native to the research area
Friend Innovation Advice	2. Who would you prefer to contact for technical advice? Friend Farmer or RADA?	Represents whether a farmer prefers a friend or RADA for innovation advice
Microwave	2. Note if you owned a microwave for the respective years of 2003-2008	Microwave ownership for each year of the period of interest
Pest Scouting	2. Did you do pest scouting? If yes, please note the plantings that it was performed on during 2003-2008	Captures when pest scouting was performed plantings during the period of interest
Pest Barrier	2. Did you plant pest barriers? If yes, please note the plantings that it was applied to during 2003-2008	Captures when pest barriers were applied for plantings during the period of interest
Adopt to Reduce Pesticide	2. Do you use these techniques to reduce your reliance on chemicals for managing pests?	Notes whether farmers understand the purpose of IPM to reduce pesticide use

Appendix 5: Data Instruments

Social Behaviour and Technology Adoption Quantitative Survey

Preliminary Individual Test Survey

Kevin Crooks
University of East Anglia, UK

September, 2008

HH ID:_____Respondent Name:_____District_____Interview Date:_____

Record the Answers for the Following Questions

1. What is your age? _______

2. Check off the level of schooling that has been completed ☐ Primary ☐ Secondary ☐ Community College ☐ University

3. Please give the names of the schools that you have attended…..............………

4. What is your main way of making a living *(Use Code Sheet)*? ☐

If other, describe………

5. Give the year and planting season for when traps, field cleaning, clean slips, selective chemical use and/or quick harvesting were first used to reduce pests *YEAR* ☐ *PLANTING MONTH* ☐

6. How many pounds of sweet potato were lost to pests in the last planting? Lbs. ………………….

Year ……... Planting Months …………………………................. Harvest Months……………………...

7. How many pounds of sweet potato were harvested in the last planting? Lbs. ...……................. Year ……… Planting Months …………………………………….. Harvest Months………………………………………………….

8. What market did you sell to for the last harvest? *Circle* Local Export Both Year ……… Planting Months …………………………………….. Harvest Months………………………………………………….

9. From most to least damaging, name the pests that have caused damage to your sweet potato since you first planted it *(Use Code Sheet)*

1	2	3	4	5	6	7	8	9	10

For the following planting times place the codes from the code sheet for the ways used to reduce pests from 2008 to 2003

Planting Month__________Year________ *Same as*, Month_______Year_____										Planting Month__________Year________ *Same as*, Month_______Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month__________Year________ *Same as*, Month_______Year_____										Planting Month__________Year________ *Same as*, Month_______Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month__________Year________ *Same as*, Month_______Year_____										Planting Month__________Year________ *Same as*, Month_______Year_____									

1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month___________Year_________ *Same as*, Month________Year_____										Planting Month___________Year_________ *Same as*, Month________Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month___________Year_________ *Same as*, Month________Year_____										Planting Month___________Year_________ *Same as*, Month________Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month___________Year_________ *Same as*, Month________Year_____										Planting Month___________Year_________ *Same as*, Month________Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month___________Year_________ *Same as*, Month________Year_____										Planting Month___________Year_________ *Same as*, Month________Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20
Planting Month___________Year_________ *Same as*, Month________Year_____										Planting Month___________Year_________ *Same as*, Month________Year_____									
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	11	12	13	14	15	16	17	18	19	20

Were any of the ways of planting from the code sheet used before 2003? ☐ Yes ☐ No

If Yes, record the codes for the ways of planting	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20

	Give the names of any people you know that give farming advice and the district that they live in *Circle the People the person goes to advice for*		Give the names of any farmer groups and its respective district(s) *Circle the Groups that the person is a member of*		Give the names of any non-farming community groups or organizations *Circle the Groups that the person is a member of*	
	Name	District	Name	District	Name	District
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

10. Please give the current barriers to investing in sweet potato IPM methods from the biggest to smallest *(Code Sheet)?*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

11. Are you a Partners member? ☐ Yes ☐ No

12. Have you ever been in a Day for Day group? ☐ Yes ☐ No

If Yes, First Year in a Day for Day group……..... Last Year in a Day for Day group……...

13. Would you be willing to take 3 hours of your time to complete a survey in the coming weeks? ☐ Yes ☐ No

14. Would you be comfortable with me asking you about who you interact with *(friends, family, etc.)*? ☐ Yes ☐ No

15. Would you be comfortable with me asking you about your farm production, sales, and profits? ☐ Yes ☐ No

Preliminary Survey

Code Sheet

Agriculture

Pests

1. Weevil aka Conga
2. Leaf Beetle
3. Weevil or Leaf Beetle Larvae aka White Grub aka Boga
4. Black Worm
5. Rats
6. June Beetles
7. June Beetle Larvae aka Boga
8. Brown/ Wire Worm
9. Mongoose

Pesticide (spelling for all?)

10. Diazinon
11. Dimatate
12. Karate
13. Molcap
14. Furadan
15. Desis
16. Silicone Spray w/ Well Grow
17. Sevin
18. Readi Mill -Fungicide
19. Noxstop

Sweet Potato Varieties

20. Eustace
21. Yellow Belly
22. Quarter Million
23. Ganja
24. Ms. Mac
25. Dor
26. Sidges
27. Minda
28. Watson
29. Clarendon
30. Pink Neck
31. Uplif
32. Hybrid
33. Shorty
34. Sugar Belly

Fertilizer

35. 18/24
36. 20/20 *(w/ Well Grow?)*
37. 11/22
38. Late Grow
39. Sulfate
40. 14/28
41. Sulfate Ammonia
42. Nitrate Balancer
43. (Unsure of Name but Applied)

Ways of Planting

44. Traps
45. Field sanitation
46. Planting pest resistant sweet potato types
47. Irrigation or keeping the ground wet around the slips
48. Crop rotation
49. Ploughing sweet potato field
50. Ploughing any adjoining fields or applying comprehensive pesticide coverage
51. Hilling and compacting the soil around the slips
52. Planting at a specific time to avoid pests
53. Space the slips specifically because of pests
54. Plant only the middle of the slip
55. Dip the slips in pesticides
56. Only use slips from fields that are perceived to have minimal pests
57. Harvest within 1 month
58. Harvest within 2 months
59. Harvest within 3 months
60. Harvest after 3 months
61. Fold Slip and Sow
62. Diazan the Earth
63. Spray every 2 weeks
64. Spray every month
65. 'Burn' *(use herbicide such as Gramoxone and/ or Reglone)* the field
66. Rotate the chemical

Adoption Barriers

67. Market Access
68. Water
69. Credit
70. Fertilizer
71. Poorly supplied trap markets
72. Poorly supplied pesticide markets
73. Inconsistent farming
74. Lack of Money
75. Irrigation pipe
76. Need for cooperative group
77. Poor yield
78. Extension insufficient
79. Labour shortage
80. Finding good quality labour
81. Pest are too invasive

Welfare

82. Occupation
83. Farming
84. Other

Post Coding

85. Actara
86. Gramoxone
87. White Fly
88. Reglone
89. Diatine *(spelling?) (repeated)*
90. Spray every 3 weeks
91. Furilate *(spelling?)*
92. Spray when needed
93. Clad Worm *(spelling?)*
94. Pest scouting
95. Pest barriers
96. Epsom salt
97. Molasses
98. Bull frogs

99. Rat poison
100. 14/28/14
101. Burn the bush on the field with fire prior to planting
102. Bats
103. Diatine *(spelling?) (repeated)*
104. Basadin
105. Malatine *(spelling?)*
106. Cows tethered on sweet potato field
107. 130. Champion *(repeated)*
108. 14/27/14 *(repeated)*
109. Spray every 7 days\
110. 132. Market restrictions *(repeated)*
111. 22/22
112. 24/27
113. 14/18
114. 11/22/22
115. Potash
116. Thieves
117. Market quality requirements
118. Bearing slips
119. 140. Glefacade *(spelling?) (repeated)*
120. Poor information *(repeated)*
121. 12/24/24
122. Claradine *(spelling?)*
123. Agent 60
124. 22/22/11

Social Behaviour and Technology Adoption Quantitative Survey

Main Survey

Kevin Crooks
University of East Anglia, UK

February-May, 2009
Hounslow, St. Elizabeth, Jamaica, W.I.

Time Begin..... End.....
Was the research and participation consent explained, did you thank them and apologize for taking up their time….
Checked by Interviewer…..
Multiple Entries Checked…..

Interview Comments
_____
_____
_____
_____
_____
_____

HH ID____ Respondent Name_____ District Field_____ Home_____ Interview Date_____

HOUSEHOLD

From 2003-2008 did you live alone? 1.Yes 2.No _____ If no, did you live with a partner? 1.Yes 2.No _____ Are you married? 1.Yes 2.No _____
From 2003-2008 how many people lived (people that eat and sleep for more than 6 months of the year) in your house? _____
Adults(18 and over)? _____ Children(0-17)? _____

From 2003-2008 did you support any adults? 1.Yes 2.No _____If yes, How many? _____ 1.college _____ 2.university _____
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 did you support any children? 1.Yes 2.No _____If yes, How many? _____ 1. infant school 2. primary school 3. secondary public 4.secondary private
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 did anyone from abroad send money to you? 1.Yes 2.No _____1. weekly 2.fortnight 3.monthly 4.every few months 5.every 6 months 5.yearly 6.after hurricane
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 did you pay any hospital bills? 1.Yes 2.No _____If yes, How many people? _____
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 did you pay for any funerals or weddings? 1.Yes 2.No _____If yes, How many people? _____
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

Of the adults you gave, how many farm? _____
Does everybody farm on the same field or does each person farm separately? _____
Which people farmed sweet potato? 1 _____ 2_____ 3_____ 4_____ 5_____
Do any people plant sweet potato together? 1.Yes 2.No _____If yes, who? on the same*(a)* or different fields*(b)*?
*Choose #s from above a*_____ *a*_____ *b*_____ *b*_____

COMMUNITY HISTORY

Were you raised in Hounslow? 1.Yes 2.No _____If yes, which district? _____
How many relatives do you have in Hounslow? _____ **1.** 1-5 **2**. 5-10 **3**. 10-15 **4**.15-20 **5**. 20-25 **6**. 25-30 **7**. 30-35 **8**. 35-40 **9**. 40-45 **10**. 45-50 **11**. 50-55 **12**. 55-60 **13**. 60 or more
Was your wife/husband/partner raised in Hounslow? 1.Yes 2.No _____If yes, which district_____
Are any of your parents from Hounslow? 1.Yes 2.No _____Are they still living? 1.Yes 2.No _____If so, do they live in Hounslow? 1.Yes 2.No _____
Are any of your wife's/husband's/partner's parents from Hounslow? 1.Yes 2.No _____Are they still living? 1.Yes 2.No _____If so, do they live in Hounslow? 1.Yes 2.No _____
How many years have you farmed or lived in Hounslow?_____
Have you ever left for more than 12 months? 1.Yes 2.No _____If yes, then tell me when and for how many years.
When_____ Years Left_____ When_____ Years Left_____ When_____ Years Left_____
When_____ Years Left_____ When_____ Years Left_____ When_____ Years Left_____
When_____ Years Left_____ When_____ Years Left_____ When_____ Years Left_____
For how many years have you been independently farming for the market? _____
What was the first year that you started planting sweet potato for market? _____ From then until now for how many years have you planted sweet potato for market?_____
Please give the 5 most important crops that you have planted, for at least 2 planting seasons, for the past 10 years? Please list them from most to least important.
1._____ 2._____ 3._____ 4._____ 5._____
Do you have any other skills for making money outside of farming? _____ _____ _____

AGRICULTURE

From 2003 – 2008 how many plots of land have you leased, owned or inherited? _____

Plot code	Which district is this plot in?	Is this field 1=inherited, 2=owned, 3= leased or 4= sharecropped? If from 2003-2008 please give the year.		What legal title or ownership rights do you have for this plot of land? 1=registered, 2=common law 3=facilities 4=none	What is the size of this plot in acres or squares?	If you were to sell this plot of land today, how much could you sell it for?	Is this plot irrigated? yes=1 no=2	Did you lease it out to others? If yes, how long have you leased it? yes=1 no=2		Has sweet potato been planted on this plot? yes=1 no=2	Distance from paved road (GIS)	Distance of plot edges					
			YEAR						YEARS		Meters	Meters					
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

Please give the size of the plots used for planting sweet potato for 2003-2008

Plot code	2003	2004	2005	2006	2007	2008	GIS Coordinates					
	Acres	Acres	Acres	Acres	Acres	Acres	1	2	3	4	5	6

TECHNIQUE USE

Code a 1.On advice of/discouraged by friends/relatives 2.On advice of/discouraged by extension agents 3.On advice of/discouraged by development workers 4.Lack of guidance/information 5.Prices decreasing 6.Too low price 7.Demand decreasing 8.No demand 9.Productivity of the activity decreasing 10.Lack of labour 11.Other activities more productive 12.Lack of capital 13.Physically not able anymore 14.Time constraints 15.External shock 16.too risky 17.too expensive to invest 18.don't have the skills for it 19.activity not profitable for HH(e.g.scale of plots too low) 20.never heard of this activity 21.beliefs 22. too difficult 23. do not believe in it 24. tried but technique bad for sweet potato 25.lack of guidance 26. lack of information source 27. use clean slips, field sanitation 28.other(specify):……...

Code b 1. friend farmer 2. RADA officer 3. ASSP officer 4. USAID trainer 5. Bodles 6. Feed store clerk 7. relative 8. neighbour farmer 9. home neighbour 10.Other ……

Code c 1.Encouraged by friends/neighbours/relatives 2.Encouraged by extension agents 3.Encouraged by development workers 4.Noticed profitability by observing others 5. Noticed prices for output were high on the market 6. Noticed many others had adopted the activity 7. demand for output rising 8.saving (for livestock) 9.low requirements of the activity 10.others(specify)……..

Do you use the following techniques for sweet potato?

Techniques	1.Have you heard about this technique? yes=1 no=2 If yes, when did you hear about it?		2.From whom did you learn it? *Code b*			3.Do you use the technique? yes=1 no=2 If yes, when did you first use it? 1=more than 10 yrs ago		4.If not used, why not? *Code a*	Did you experiment with this before somebody trained you? yes=1 no=2	What influenced your decision to adopt? *Code c*
		YEAR	who	Name	HH ID		YEAR			
1. pheromone traps						\\\\\	\\\\\\\\\			
2. dipping slips in insecticide										
3 spraying chemical when needed and rotating them in order to prevent pests from becoming immune to them										
4. choosing slips from minimally infested fields										
5. field sanitation ('burning' the field after planting, removing old planting material, and weeds) for pests										
6. planting away from old fields or destroying (ploughing, comprehensive pesticide application and/or trap setting) them for pests										
7. crop rotation for pests										
8. removing wild slips for pests										
9. deep ploughing for pests										

Have you ever planted a slip nursery? 1.Yes 2.No _____
Do you use these techniques to reduce your reliance on chemicals for managing pests? 1.Yes 2.No _____
Do you apply the same amount of chemicals regardless of the use of these techniques? 1.Yes 2.No _____

The purpose of this set of techniques that I just asked about is to increase the percentage of exportable sweet potato. Which is your belief with respect to them?
1. that you need more information about these techniques 2. that you understand the techniques and need more export market support _____

Code d 1.January 2.February 3.March 4.April 5.May 6.June 7.July 8.August 9.September 10.October 11.November 12.December
Code e 1. 2003 2.2004 3.2005 4.2006 5.2007 6.2008

From 2003-2008 when you planted sweet potato did you ever plant next to an old field (yours or another farmer's)? 1.Yes 2.No _____If Yes, when?
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Did you ever do this before 2003? 1.Yes 2.No _____

For the years that you planted sweet potato did you rotate chemicals during planting? 1.Yes 2.No _____ If Yes, when?
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Did you rotate chemical prior to 2003? 1.Yes 2.No _____

Did you do pest scouting? 1.Yes 2.No _____ If Yes, when?
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Did you do pest scouting prior to 2003? 1.Yes 2.No _____

Did you plant pest barriers (planting corn around the field)? 1.Yes 2.No _____ If Yes, when?
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Year_____ Planting Month_____Year_____ Planting Month_____Year_____ Planting Month_____
Did you plant pest barriers (planting corn around the field) prior to 2003? 1.Yes 2.No _____

IPM TEST

How many traps are required for controlling the sweet potato weevil for the following field sizes:
-less than an acre_____ -1 acre_____ -2 acre_____

When should the trap(s) be placed in the field: 1.before planting 2.at planting 3.later in the crop 4.when pest is seen 5.not used
_____ others_____

How often do you move the trap within the field? 1. once per week 2.monthly 3.do not move, the trap is stationery _____
others_____

Do you know why traps need to be moved within the field? 1.yes (explanation required) 2.no
_____
How often do you change the pheromone trap? 1.monthly 2.bi-monthly 3.once for the duration of crop 4.I don't know _____
other_____

How many traps do you need to control the weevil for the duration of one crop for 1 acre (approx. 4 months)? 1.none 2.one 3.two 4.three 5.three to four 6.I don't know
_____ other_____

Do you know how to construct the trap? 1.yes (explanation required) 1.no
_____
Does the trap height above the sweet potato canopy depend on the development of foliage/leaves? 1.yes 2.no 3.I don't know
_____

Do you use any innovation for the better use of traps? 1.yes 2.no
_____
How do you store pheromone traps? 1.refrigeration 2.without refrigeration
_____
Can other pests be controlled by the pheromone trap? 1.only adult weevils 2.yes, other pests (explanation required) 3.I don't know
_____
What other methods of weevil control can you use in your field?

crop rotation: 1.yes 2.no 3.I don't know _____
weed control: 1.yes 2.no 3.I don't know _____
chemical control: 1.yes 2.no 3.I don't know _____
reaping within 3 months (quick harvesting): 1.yes 2.no 3.I don't know _____
good soil preparation: 1.yes 2.no 3.I don't know _____
chemical dip of slips prior to planting: 1.yes 2.no 3.I don't know _____
selection of slips (top part of slip): 1.yes 2.no 3.I don't know _____

Do you think soil sampling is important prior to selecting a field for planting sweet potato? 1.yes 2.no 3.I don't know
_____
If yes, would you sample for? 1.nutrients 2.soil pests 3.both
_____
Are you going to establish a field during the soil sampling if you see grubs (Bogas)? 1.yes 2.no 3.I don't know
_____

EXTENSION INFLUENCE

What do you think about RADA? 1. very helpful 2. sometimes helpful 3.okay 4.not that helpful 5.not helpful at all
_____
From 2003-2008 did you speak to a RADA officer? 1.Yes 2.No _____If no, why? *If no then skip the remaining questions in this section up to training attendance*
1. too hard to access 2. prefer personal knowledge 3. prefer doing for one's self 4. don't trust them

If you don't trust them, why?
1. political bias of assistance 2. personal bias of assistance 3. bad advice from previous experience 4. did not respond to previous enquiry 5. took too long to respond previously
6. officers seem apathetic 7.others(specify)……..

_____
When was the last time that you spoke to a RADA officer? Year_____ Month_____

From 2003-2008 how often did you speak to a RADA officer? 1. Never 2.Yearly 3.Several Times a Year 4.Monthly 5.More than Once a Month
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

Which do you usually do? call a RADA officer go to the office
From 2003-2008 did you ever call a RADA officer for advice? 1.Yes 2.No _____If yes, how long did it usually take for an officer to respond?
1. A day 2. less than a week 3. a week, a month 4. more than a month _____ 5. Never
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 did you ever visit a RADA office for advice? 1.Yes 2.No _____If yes, how long did it usually take for an officer to respond?
1. A day 2. less than a week 3. a week, a month 4. more than a month _____ 5. Never
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

From 2003-2008 which office did you usually go to? Santa Cruz Watchwell

From 2003-2008 has a RADA officer ever visited your field? 1.Yes 2.No _____Ever for sweet potato? 1.Yes 2.No _____
If you visited the office during the noted hours was your concern attended to?
If once, answer yes or no? 1.Yes 2.No _____If on multiple occasions, answer always, sometimes, or never?_____

Have you ever spoken to a RADA officer about sweet potato IPM (traps, dipping slips, crop rotation, slip selection, site selection, field sanitation) or pest control?
1.Yes 2.No _____If so, how many times and when? _____ **1**. 1-5 **2**. 5-10 **3**. 10-15 **4**.15-20 **5**. 20-25 **6**. 25-30
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

Did you mostly go to them or did they come to you? former or latter

Which officer was most reliable from 2003 - 2008? _____

From 2003-2008 did you ever attend a sweet potato pest control training? 1.Yes 2.No _____ If yes, how many? _____
When and where for each? *Use Code d and Code e for year and month respectively*
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____
Year_____ Month_____District_____ Farmer Plot_____Organization_____

If it was RADA, which officers did the
trainings?.....

Have any other non-farmers given you information about sweet potato integrated management? 1.Yes 2.No _____If Yes, Who?

……

Which do you prefer? 1. traditional planting methods 2. the most effective methods, regardless of tradition

_____

Who would you prefer to contact for technical advice? Friend Farmer or RADA Why? Easier access, more trusted, more experience, Other_____

Who would you prefer to contact for market advice? Friend Farmer or RADA Why? Easier access, more trusted, more connections, Other_____

What is your main information source on sweet potato? Friend farmer or RADA? Please give name_____

In order for you to adopt a technology do you need a RADA officer to explain it to you? 1.Yes 2.No _____

Have you ever tried to buy the pheromone trap but it was sold out? 1.Yes 2.No _____
2003_____ 2004_____ 2005_____ 2006_____ 2007_____ 2008_____

WELFARE

Debts

	Feed store debt?	Did you have problems financing it? yes=1 no=2	Bank debt?	Did you have problems financing it? yes=1 no=2	NIC overdue payments?	Did you have problems financing it? yes=1 no=2
2003						
2004						
2005						
2006						
2007						
2008						

Livestock	Cows	Goats	Sheep	Chickens
2003				
2004				
2005				
2006				
2007				
2008				

Household Characteristics

House	# of Rooms	Bedrooms	Bathrooms	Living	Dining	Veranda	House	Wall	Roof	Kitchen	Water	Electricity	Windows	Toilet
2003														
2004														
2005														
2006														
2007														
2008														

Durables

Durables	Stove	Refrigerator	Washing	Dryer	Radio	TV	Stereo	Microwave	Vehicle, 2 if truck	Motorbike	Bicycle	Cell	Camera	Computer
2003														
2004														
2005														
2006														
2007														
2008														

MARKET ACCESS

From 2003-2008 how would you rate your sweet potato market access? -very good -good -okay -not so good -bad
Besides calling the buyers you know, where and who would you go to in order to find sweet potato markets?
……
.
From 2003-2008 how many buyers did you know of or sell to? _____
From 2003-2008 how many of those buyers sold solely to the local market? _____
From 2003-2008 how many of those buyers sold solely to the export market? _____
From 2003-2008 how many of those buyers sold to both the local and the export market? _____
Please give the names and if possible the phone numbers of the buyers that you have sold to since 2003.

Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both
Name…… Phone…… Local Export or Both

SOCIAL INTERACTIONS

Are there any people on the list that you request advice from, but you don't provide advice for?
Please list……...

Please give the names of any labourers that have worked on your sweet potato field from 2003-2008:
……

Code f. 1.ASSP Hounslow Producer's Group 2.JAS Bigwoods 3.Hounslow Water Users Association 4.Hounslow Specially Authorized Water Users Group 5.Geneva PMO

Give the names of all farming and water groups that you have been in from 2003 – 2008 *Code f*		Give any positions that you held in those groups					
Att. Years	Names	1	years/mnths	2	years/mnths	3	years/mnths

	Please choose the farmers from the list that have farmed next to your field(s) for the following years											
2003												
2004												
2005												
2006												
2007												
2008												

If you were able to get the benefits of the group yourself, would you prefer doing it yourself rather than joining the group? 1.Yes 2.No _____

**********GO TO NETWORK SHEETS**********

Sweet Potato IPM advice list *Group Size* _____

1. Please name the people on the list whom you have received advice about sweet potato IPM (traps, dipping slips, crop rotation, slip selection, site selection, field sanitation, deep ploughing) or pest control from for 2003-2008

2. Then list those that you have not gone too but are known in the community for giving advice about sweet potato IPM or pest control.

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside* Field	Home	Gender *Male=1 Female=2*	relation to respondent *code c*	What is the quality of their advice? 1=very good 2=good 3=okay 4=not so good 5=useless	If the person is an advice link put 1 if a community advisor put 2	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	From 2003-2008, how often have you spoken with this person? *1 – daily 2 – weekly 3- monthly 4 – every few months 5- 6 months 6 – yearly 7 -never*	for how many years have you been good friends or 'bredren' with this person Years	For 2003-2008, When was the first and last year that you received sweet potato IPM information from this person? Years First	Last

Planting Material Network List *Group Size* _____

Please list any farmers on the list that you have shared slips or any other planting material with for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside*		Gender *Male=1 Female=2*	relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	From 2003-2008, how often have you spoken with this person? *1 – daily 2 – weekly 3- monthly 4 – every few months 5- 6 months 6 – yearly 7 -never*	For the planting material do you.., *1-only give 2-only receive 3-share* planting material?	Which planting material has been shared? *1-Potato 2-Peanut 3-Peas 4-…… 5-…… 6-…… 7-…… 8-……*	for how many years have you been good friends or 'bredren' with this person	For 2003-2008, When was the first and last year that you shared planting material with this person?	
		Field	Home							Years	Years	
											First	Last

Market Sharing Network List *Group Size* _____

Please list any farmers that you are connected to on the list that you have shared market with for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside* Field	Home	Gender *Male=1* *Female=2*	relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	What is the quality of the information? 1=very good 2=good 3=okay 4=not so good 5=useless	From 2003-2008, how often have you spoken with this person? *1 – daily* *2 – weekly* *3- monthly* *4 – every few months* *5- 6 months* *6 – yearly* *7 -never*	for how many years have you been good friends or 'bredren' with this person Years	For 2003-2008, When was the first and last year that you shared market information with this person? Years First	Last

Hired Labour Network List *Group Size* _____

Please list all the farmers from the list that you have ever hired for days labour on your sweet potato field for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside*		Gender *Male=1 Female=2*	relation to respondent *code c*	What is the quality of the labour? 1=very good 2=good 3=okay 4=not so good 5=useless	On a scale from 1 - 5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	From 2003-2008, how often have you spoken with this person? *1 – daily 2 – weekly 3- monthly 4 – every few months 5- 6 months 6 – yearly 7 -never*	for how many years have you been good friends or 'bredren' with this person	For 2003-2008, When was the first and last year that you hired this person for days work?	
		Field	Home						Years	Years	
										First	Last

Family Network List *Group Size* _____

Please list any farmers that you are a relative to (including in-laws), to the 3rd degree (2nd Cousin)

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside* Field	Home	Gender *Male=1* *Female=2*	relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	For 2003-2008, how often have you spoken with this person? *1 – daily* *2 – weekly* *3- monthly* *4 – every few months* *5- 6 months* *6 – yearly* *7 -never*

Informal Insurance Network List *Group Size* _____

Please list any farmers on the list that you have lent money to, also, list any farmers that you have borrowed money from for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *1- Hounslow* 2- *Ridgepen* 3- *Bethany* 4- *Bigwoods* 5- *Newell* 6- *Watchwell* 7- *Mountainside* Field	Home	Gender *Male=1* *Female=2*	relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	From 2003-2008, how often have you spoken with this person? *1 – daily* *2 – weekly* *3- monthly* *4 – every few months* *5- 6 months* *6 – yearly* *7 -never*	For how many years have you been good friends or 'bredren' with this person	Do you 1= lend, 2=borrow 3=both from this person?	For 2003-2008, When was the first and last year that you lent or borrowed money with this person? Years First	Last

Partners Network List *Group Size* _____

Please list any farmers that you are connected to on the list that you have been in a partners group with for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK		Locations of this person *8- Hounslow* *9- Ridgepen* *10- Bethany* *11- Bigwoods* *12- Newell* *13- Watchwell* *14- Mountainside*			relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	From 2003-2008, how often have you spoken with this person? *1 – daily* *2 – weekly* *3- monthly* *4 – every few months* *5- 6 months* *6 – yearly* *7 -never*	for how many years have you been good friends or 'bredren' with this person	For 2003-2008, When was the first and last year that you did partners with this person?	
HH No.	net-work ID No.	Field	Home	Gender *Male=1* *Female=2*				Years	Years First	Last

Tool Sharing Network List *Group Size* _____

Please list all the farmers from the list that you have ever lent a tool to or borrowed a tool from for 2003-2008

Code c: 1.son/daughter 2.Grandchild 3..father/mother 4.sister/brother 5.cousin 6.uncle/aunt 7.son/daughter-in-law 8.brother/sister-in-law 9.mother/father in law 10.grandparent 11.grandparent-in-law 12.other blood bond 13.personal friend, but no blood bond 14. family friend, but no blood bond 15. neighbour farmer 16. home neighbour 17.other……..

LEAVE BLANK HH No.	net-work ID No.	Locations of this person *15- Hounslow* 16- *Ridgepen* 17- *Bethany* 18- *Bigwoods* 19- *Newell* 20- *Watchwell* 21- *Mountainside* Field	Home	Gender *Male=1* *Female=2*	relation to respondent *code c*	On a scale from 1 -5 (5 being the highest, trusting them with managing your money and 1 being you would not trust them to help you crossed the road) how much do you trust this person?	How often do you speak with this person? *1 – daily* *2 – weekly* *3- monthly* *4 – every few months* *5- 6 months* *6 – yearly* *7 - never*	For 2003-2008, how long have you been good enough friends where you borrow a machete or hoe from, or lend one, to this person? Years

Housing

Type of House

125. Separate detached house
126. Semi-detached house
127. Part of a house
128. Apartment building
129. Town-house
130. Improvised/ temporary housing unit
131. Part of commercial building

Material of Walls

132. Wood
133. Stone
134. Brick
135. Concrete
136. Clock and Steel
137. Wattle/Adobe

Roof

138. Zinc
139. Deck
140. Zinc and Deck

Windows

141. Partially windowed
142. Glass louvers
143. Wooden louvers
144. Glass and wooden louvers
145. Single glazed
146. Double glazed
147. Glazed and louvers

Kitchen

148. Inside
149. Outside

Water

150. Pipe
151. Tank/Drum
152. Natural source

Toilet

153. Inside
154. Outside
155. Pit

Qualitative In-Depth Interview and Focus Group Questions

Types of People for In-Depth Interviews

1. **Elderly** – To get a social history of the community and how the community has come to its current state. With a particular emphasis on social trust and sharing information, resources, and labour.
2. **Innovators (early adopters)** – To understand why they adopted early and what their information sources were. How do they interact differently? Are they more independent?
3. **Late adopters** – To understand why they waited to adopt and what their information sources were. Do they interact differently?
4. **Central Nodes i.e. Social Analysts (actors that have high out-degrees for farming advice)** – Main source for getting group characteristics for developing instrumentation questions, as they have connections throughout the community
5. **Non-adopters** – What prevented them from adopting? Are there particular characteristics specific to non-adopters? Do they interact differently?
6. **Export planters** – How come they are able to sell exclusively to the lucrative export market? How are they able to get this connection?
7. **Farmers with minimal pest damage for last planting** – What do they think is the reason for their low pest damage levels
8. **Long time Day for Day members** – Labour sharing history in the community
    - History of day for day in the community
    - How do people usually form Day for Day groups?
    - Do your day-for-day partners influence your farming decisions and practices? Why?
9. **Elderly partners members** – To understand informal insurance in the community
    - History of partners in the community
    - How do people usually form partners groups?
    - Do your partner members influence your farming decisions and practices? Why?
10. **Sweet Potato Traders** – To understand how they choose farmers. To have an idea of how access networks are established, from their point of view.
11. **Heads of Farmer Groups** – To understand the role of formal farming groups in the community.

Training Personnel In-Depth Interviews

The training personnel in-depth interviews are intended to extract information on how they disseminate IPM and why, to see if they take notice of informal social connections for diffusion, and their perception of how farmers learn.

1. What organizations have provided sweet potato pest control training since 2000? Was their training coordinated with RADA's? Was their training prior to that time?
2. Ask about the USAID workers Mr. Eric Smith and the Honduran advisor with regards to their role in teaching sweet potato pest management

3. What methods were used to disseminate the technology? Field schools? Demonstration plots? On farm trials? Contact farmers? Are informal social characteristics of the community taken into account? Why do you employ those methods?
4. What is your perception of how farmers learn about technologies and sweet potato IPM in particular? Are social groups and characteristics important? What do you think the social effects are with respect to technology adoption and specifically, sweet potato IPM? Can you give me any specific issues regarding the sharing of farming information in the community?
5. When you think about it, do you think that better connected farmers are therefore better farmers? Or do you think that these farmers are just more outgoing and are better farmers in the first place?
6. It seems that social trust has deteriorated over the years; do you think this has had an effect on how information is shared, and thus on the quality of farming?
7. How important is the spatial arrangement of traps for controlling the weevil and other sweet potato pests within the Hounslow, Ridgepen and Bethany area?
8. Why have so many people started planting sweet potato in the past few years? Has the ministry been promoting it? Has ASSP in Ridgepen been promoting it?
9. Why do you think 2005 had the largest amount of trap adoption?

General Questioning

1. **Social State of the Community**
    - Can you tell me about the community's current social state? Is the community fractured? How and why?
    - What do you think about the level of trust among people in the community? Why?
    - Generally speaking, in the Hounslow, Ridgepen and Bethany area, would you say that most people can be trusted or that you can never be too careful in dealing with people? Please reflect on all interactions and not just on the people that you normally interact with.
    - If you lent money to someone in the community would you expect them to pay you back? Is this normal?

2. **Informal Social Groups in the Community and their Characteristics**
    - Can you tell me about the social groups in the community? What types of people tend to hang-out with each other? Why?
    - Are there clear social groups? Are there classes?
    - How important is land ownership and wealth to social relations?

3. **Informal Organizations – Day-for-Day (Morning Sport), Partners, etc.**
    - In your perspective do people prefer using family, hired or day-for-day labour? Why?

4. **How Is Information Shared in the Community with Respect to Informal Groups**

- Ask questions concerning why farmers adopted and why they did not, particularly with respect to the adoption time. What were the social influences of this behaviour (social pressure, imitation, profit, etc.)?
- Do you think there are groups of farmers that hold information exclusively?
- Are there certain groups that have more access to information? Why?
- When you think about it, are there certain people that you prefer to get farming advice from, such as family, farmer group members, neighbours, etc.? Why?
- Do you rely on other farmers, RADA or somewhere else for farming advice? Why? Is this common?
- Do your relatives influence your farming decisions and practices? Would you say that this is common or uncommon?
- How long has this been occurring?
- How important is farming knowledge to relationships?

5. **RADA, as well as other ag-support institutions, and their Role in Introducing Technologies, as well as How they Disseminate Information.**
    - What is the quality of extension?
    - What is your relationship with RADA? What is the relationship of RADA with the rest of the community? What do they provide to the community?
    - It seems that farmers are uneasy with joining farmer groups, why is this? Does it depend on the group?
    - Besides RADA, have any other groups taught farmers about pest control techniques? How did they teach farmers? Did they target certain farmers, did they give a demonstration to all the farmers, or did they do something else? Were you taught any techniques directly?

6. **Market Access and Informal Social Groups**
    - Do certain farmers have a special relationship with higglers? Why? Are they given preference? Do you think there are certain groups of people that have better access? Why would these groups have better access than others? How do certain farmers gain access to the market while others do not?

Focus Group Discussions: Formal Farmer Groups

The purpose is to bring out the same issues as in the in-depth interviews, but in a group setting where people can discuss, and the answers can be expanded further. In addition, answers can be argued and there is the advantage of the possibility of consensus. Market access questions will not be discussed because it might anger many since that is their avenue for income, so they would want to protect that information.

General Questioning

1. How is information on agricultural technologies usually learned?
2. What is the most significant technology training source, such as RADA, ASSP, USAID, CIDA, etc.? Do they train people differently?
3. Does it usually take a long time for information to spread about a new technology?
4. How many people learn from their neighbours? How many from their family? How many from day-for-day or partners members? (at this point, looking at the amount for each group, ask why there is a difference)
5. Are there any other groups of people that people learn from?