ABSTRACT

The adoption of new agricultural innovations is low across sub-Saharan Africa (SSA) which has resulted in low levels of productivity and exacerbated food security concerns. As a result, it is a key priority of many African governments to develop their agricultural sectors through the promotion of new agricultural technologies. Previous attempts of agricultural development in SSA have had limited success with many of the failures being attributed to the traditional top-down and linear knowledge transfer in which research bodies and governments act as teachers and farmers are their students. The failure of this approach has resulted in a new paradigm of agricultural innovation emerging, Agricultural Innovation Systems (AIS). This approach acknowledges the importance of all actors, organisations and institutions that directly or indirectly affect innovation creation and adoption. In AIS, farmers should be treated as equal partners and co-developers of knowledge.

In AIS, innovation creation and diffusion require individuals to collaborate together and to spread awareness of the innovation, meaning social relationships and social networks are at the core of the innovation process. Policies that focus on social networks and the social capital they generate may therefore be able to improve the functioning of AIS by facilitating cooperation and knowledge diffusion. This thesis seeks to delve into such policies to identify whether they are successful and if they can be improved. Using social network analysis and inferential statistics, informal farmer networks and farmer cooperatives are analysed to better understand policies that use social networks to promote agricultural development.

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This thesis initially begins by providing an overview of AIS in Kenya and Ethiopia. It highlights the differences in their institutional contexts and how this effects the operation of AIS and innovation adoption. The thesis then examines the network structure of farmers informal networks and how our understanding of network structure can be used to improve farmer-to-farmer extension services. Finally, this thesis looks at formal farmer networks in the form of

agricultural cooperatives. It explores whether government policy can effectively create cooperative networks that generate social capital and benefits for cooperative membership.

The results of these studies and overall thesis conclusions highlight the importance of selecting the right individuals to act as gatekeepers to the wider farmer networks. These individuals may be trained as lead farmers in farmer-to-farmer extension systems or may be cooperative leadership in more formal settings. However, they should be respected and well-placed within a network if they are to successfully encourage collective action or promote innovation diffusion. It is also found that whilst policies that focus on social networks can help improve AIS, attention also needs to be given to the wider policy environment to ensure it promotes innovation and adoption through other channels.

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LAY SUMMARY

Sub-Saharan Africa (SSA) is experiencing low levels of agricultural productivity which is largely attributed to the limited use of agricultural innovations by smallholder farmers. It is therefore a priority for many SSA governments to promote new technologies and increase their use amongst smallholders in the region. Recent literature tends to look at agricultural innovation in terms of the broad range of actors, institutions and systems that work together and directly and indirectly affect innovation creation and adoption. This approach is called Agricultural Innovation Systems (AIS) and offers an encompassing perspective on innovation.

Social networks, which are the interactions and relationships between people, are important in AIS as they result in the generation of social capital, which represents the positive outcomes that arise from social interaction. Social capital can be used as a productive resource by individuals and can help improve their economic position. In AIS, social networks and social capital can encourage collaboration, facilitate the sharing of trusted information and enable farmers to work together and reap the benefits of collective action. Many existing agricultural policies have sought to capitalise on these positive effects of social networks and social capital and use them to drive agricultural development. However, many of these policies do not consider the social structure or power dynamics within smallholder farmer communities which has limited their effectiveness.

This thesis focuses on two existing policies in SSA that use social networks and the social capital they generate to promote agricultural development and innovation adoption. With a specific focus on the dairy sectors of East Africa, this thesis initially examines the AIS of Kenya and Ethiopia. It demonstrates that institutional environments can have an impact on how the AIS operates and therefore a one-size-fits all approach to innovation policy is inappropriate. In the Kenyan context, a lack of government intervention in the dairy sector has meant informal institutions, such as informal seed exchange and farmer-to-farmer (F2F) information transmission, are important in technology adoption. In the Ethiopian context, top-down policies

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Building on these findings, this thesis first analyses F2F extension in Kenya using social network analysis. It discusses the differences in network structures and the benefits of selecting farmers who are hold certain network positions to be trained and then incentivised to educate other farmers in their network. The thesis then analyses the creation of agricultural cooperatives through government policy in Rwanda, a country with a similar institutional environment to Ethiopia. The results showed that whilst successful, these cooperatives could be improved by ensuring the leadership are accountable for their actions. Finally, this thesis summarises how both F2F extension and agricultural cooperatives can overcome some failures and uncertainties in AIS. It argues that both policies can help overcome AIS failures, but the extent to which they can do so depends on their design. It is also noted that for social network policies to be successful, other innovation relevant policies must also support smallholder innovation adoption.

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Chapter One: Introduction

1.1 Motivation of the Research

Agriculture in sub-Saharan Africa (SSA) is dominated by smallholder farmers who experience low levels of productivity as a result of low technology use. Whilst their counterparts in Asia and Latin America experienced significant increases in productivity throughout the 1960s due to increased use of modern inputs, SSA did not partake in this 'green revolution' (Sheahan & Barrett, 2017). As a result, African smallholders have remained mostly subsistence farmers and, in many circumstances, their agricultural methods have resulted in land degradation including salination, desertification and soil erosion (Godfray, et al., 2010).

In recent years, the need for Africa's own green revolution has become more pressing as climate change models predict that erratic weather patterns will affect food production and exacerbate food insecurity in the region (Clay & King, 2019). This has the potential to push smallholder farmers further into poverty as many rely on farming for their subsistence. There is therefore a need for governments and relevant institutions to introduce policies that can encourage farmers to adopt new agricultural innovations and promote a move towards more sustainable and resilient practices.

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Understanding the barriers to modern technology use in SSA has been the focus of many studies. Some have found that uncertain rainfall, high levels of disease amongst livestock and the increased incidents of human diseases, such as HIV, all create uncertainty around how much income new technology will generate (Ehui & Pender, 2005). Similarly, other studies have argued that the declining global food prices in the 1980s and 1990s meant there was little incentive for governments to invest in their agricultural sectors (Diao, et al., 2008). Instead, a strong urban bias in government spending resulted in the under-development of rural areas, impeding the transportation of agricultural goods and the ability of farmers to participate in long term planning (Ehui & Pender, 2005). On top of these concerns, the 'one size fits all' approach to technology adoption which was promoted across Asia is not transferrable to the environmentally diverse and complex agricultural systems in SSA (Toenniessen, et al., 2008).

The complexity of the barriers to adoption faced by smallholders means a single solution or policy approach to overcome them does not exist. However, one area of research that has been gaining traction over the last few years is the role of social capital, and the networks that generate it, in providing smallholders with the opportunities and knowledge required to adopt new agricultural innovations. Social capital is ultimately the positive product of social interactions. It refers to the social networks and relationships that form them and the potential these interactions have to generate benefits for both the individual and collectively for society. Social capital is therefore viewed as a productive asset that has many properties, including ''transformation capacity, … substitutability, opportunities for decay (maintenance), … [the] ability to create other capital forms, and investment (disinvestment) opportunities' (Robison, et al., 2002, p. 1).

Evidence suggests that social capital can support innovation use amongst smallholders through multiple channels. For example, a study in Ethiopia found that membership to groups such as informal lending groups, credit associations and labour sharing agreements had a positive effect on technology adoption by increasing access to certain assets (Wossen, et al., 2014). Other studies have shown how interactions between farmers encourages information sharing, helping knowledge spread through the community or network (Rijn, et al., 2012). This knowledge can reduce the perceived riskiness of innovations as smallholders are more likely to trust information that comes from peers.

The positive association between social capital and technology adoption is well documented and policy makers have sought to capitalise on this through various policies and interventions. For example, the creation of agricultural cooperatives by governments seeks to bring farmers together so they can cooperate and reap the benefits of collective action. However, for such an approach to be successful, social capital between members will need to exist, and this can be challenging for governments to 'socially engineer' (Portes & Landolt, 2000). Despite the existence of such policies, very little attention is paid to the social networks that underpin social capital and that can provide insight into intra-community dynamics, information flows and power relations that exist within communities and that are important when trying to ensure interventions reach those who need them (Hoang, et al., 2006). This research therefore seeks to focus on social networks and their structures to understand how existing policies that promote innovations in SSA can be made more effective.

1.1 Research context

As mentioned previously, one of the reasons for the failure of the 'green revolution' in SSA was the one-size fits all approach to technology promotion. The agricultural sector in SSA is diverse with heterogenous actors having a range of needs, demands and motivations. It therefore seemed impractical, and arbitrary, to try and cover the whole of SSA agricultural sector in this thesis. Alternatively, selecting an economically important sub-sector that was facing many of the barriers and issues felt across the wider agricultural landscape was deemed to be a more effective approach. This thesis therefore focuses on the dairy sector in East Africa and how various institutions can use social capital and social networks to improve the uptake of innovations within it. Whilst many of the conclusions of this thesis are highly specific to the East African dairy sector, several high level and general approaches to policy development are suggested in the final chapter which can be applied to the broader SSA agricultural sector.

The exact boundaries of East Africa are undefined, with different interpretations including anywhere up to the 19 countries that are all on the eastern side of the African continent. The dairy sector in East Africa, however, tends to be focused within Kenya, Ethiopia, Tanzania, Rwanda and Uganda, highlighted in Figure 1.1. Going forward, the term East Africa will be used to refer to these five countries. These countries are considered to have high dairy potential due to ideal climatic conditions yet despite this dairy productivity has remained low. This has largely been attributed to the low use of modern inputs which have resulted in the region remaining a net importer of dairy. East Africa produced 68% of the continents milk in 2013 and dairy is the fastest growing sub-sector and has the potential to generate significant economic returns (Bingi & Tondel, 2015). If invested in correctly, governments could see increases in GDP and improved farmer livelihoods. Data from three East African countries is used in this thesis, Ethiopia, Kenya and Rwanda. A profile of each country is given below.

Figure 1.1: High dairy potential countries in East Africa

1.1.1 Ethiopia

Chapter 3 of this thesis uses data from Ethiopia. Ethiopia is a landlocked country with a population of around 117 million (World Bank, 2021). It has a diverse climate, with equatorial rainforest in the south and southwest of the country and desert like plains in the east. The country is dominated by highlands and large plateaus. The majority of the country's population and the capital, Addis Ababa, are located in the highlands. Agriculture, forestry and fishing make up around 40% of the Ethiopia's GDP and agriculture accounts for 67% of employment (World Bank, 2021). Food insecurity is high in the country even with various government approaches to try and overcome it (Jiren, et al., 2020). Within Ethiopia, the highlands offer a favourable agro-ecological environment for dairy, yet despite this and the high number of dairy cattle, Ethiopia remains a net importer of dairy products (Kebebe, et al., 2015). Smallholders are responsible for around 97% of milk production (Getabalew, et al., 2019) meaning any attempts to commercialise the sector will need to have smallholders and their technology use at the core

The Ethiopian government is heavily involved in the country's dairy sector, providing nearly all the extension services and publicly funding dairy research (Järnberg, et al., 2018) (Kebebe, et al., 2015) (Tefera, et al., 2010). This has meant that in rural areas where smallholders are more isolated, they have to rely on public actors for all their information (Tefera, et al., 2010). Even in more urban settings, high levels of bureaucracy and government interference has prevented private actors from having much influence (Aranguiz & Creemers, 2019). The government therefore plays a substantial and dominating role in communicating new innovations to smallholders and promoting their uptake. However, to date government policies have mostly failed to develop the dairy sector with low levels of knowledge diffusion, low levels of entrepreneurship and poor market development being cited as the main reasons (Kebebe, et al., 2015)

1.1.2 Kenya

Data from Kenya is used in Chapters 3 and 4 of the thesis. Kenya is a diverse country with a population of over 50 million with 36% of the population recorded to be living in poverty in 2015 (World Bank, 2021). The Kenyan government's flagship policy is to 'transform Kenya into a newly industrialising, middle-income country… by 2030' (Kenyan Government, 2017) and includes significant changes to the agricultural sector including better disease control for livestock, improved irrigation systems and access to cheaper fertilisers. In 2010 Kenya voted for devolution to be introduced which would see the transfer of many fiscal and administrative powers to the 47 county governments (D'Arcy & Cornell, 2016). It was hoped that decentralising power in this way would resolve many of the underlying issues in Kenyan politics, particularly the dominance of certain ethnic groups and the exclusion of others

(Boone, et al., 2016). The resulting outcome has been increasing differences, socially and economically, between counties due to the cultural traditions and geographical attributes of each region. Kenya's diversity does not just apply to its social and economic portfolio, but also to the natural and climatic conditions. The country has three main climatic zones, a subtropical climate in the west and southwest, hot and dry in the north and east and a tropical humid climate along the coast.

Agriculture makes up around 24% of Kenya's GDP and is responsible for 54% of employment (World Bank, 2021). Dairy is an important agricultural sub-sector with Kenyan dairy consumption being the highest in Africa. In the Kenya Dairy Master Plan produced by the Kenyan government, it was predicted that by 2030 domestic demand for milk would have more than doubled compared to 2010 levels (Bingi & Tondel, 2015). The need to increase dairy production in line with rising demand is therefore pressing. Currently, the Kenyan government provide some regulation in the sector, for example setting milk standards, however they intervene relatively little when it comes to information transmission and technology promotion. Alternatively, the sector tends to be dictated by market forces and private or non-government actors (Kaitibie, et al., 2010). As a result, there are gaps in the formal infrastructure, such as access to finance as many smallholders may be deemed too high risk to lend to. These gaps have led to an increase in informal institutions such as informal savings groups (Wilkes, et al., 2019).

1.2.3 Rwanda

Chapter 5 of this thesis uses data from Rwanda. Rwanda is a landlocked country, with mountains in the west and dry savannah in the southeast. It is part of the Great Lakes region of Africa. The population is around 15 million and 62% of the workforce are employed in the agricultural sector, with contributes to 24% of Rwanda's GDP (World Bank, 2021). In 1994 Rwanda experienced a mass genocide which left the country segregated. The new government which took over post-genocide adopted a highly hierarchical structure to reduce corruption (Biedermann, 2015). They pushed policies that promoted cohesion amongst civil society, for example they introduced mandatory community work that citizens must take part in once a month (Hasselskog & Schierenbeck, 2015).

The Rwandan dairy sector has seen considerable growth as a result of government policies which have improved milk production, productivity and quality. Maintaining the hierarchical approach to governance, the government has instigated a highly controlled cooperative system in which smallholders are made to join agricultural cooperatives and instructed what they can grow and how (Cioffo, et al., 2016). The government has also adopted many pro poor policies such as 'Girinka' in which cows were given to poor families. The sector is guided by the Rwanda Dairy Competitiveness Program and the Rwanda Dairy Development Policy which have both been considered successful (Habiyaremye, et al., 2021). NGO's and international organisations also play an important role in the Rwandan dairy sector with the National Agricultural Policy published in 2018 including private-led development and foreign investments as a major component.

1.2 Thesis objectives and aims

This thesis aims to answer the following research questions:

Main research question:

How can social networks and the social capital they generate be used by policy makers to promote the uptake of agricultural innovations in SSA?

Sub-research questions:

Where are the weaknesses in existing Agricultural Innovation Systems?

How can pre-existing social networks be incorporated into policy to overcome these weaknesses?

Can social networks and the social capital it generates be created through government policy to overcome these weaknesses?

To answer these research questions, this thesis places itself within the Agricultural Innovation Systems (AIS) paradigm, which is discussed in depth in Chapter 2. The AIS paradigm provides a framework for how actors within an innovation system should interact to facilitate effective innovation creation and diffusion. Chapters 3, 4 and 5 of this thesis are standalone studies which each answer one of the sub-research questions. An overview of how each chapter feeds into the overall research question is shown in Figure 1.2. Chapter 6 of this thesis synthesises the results of the previous chapters and presents policy recommendations for how social networks and social capital can be used to improve AIS.

Chapter 2 reviews the existing literature on AIS and the role of social networks within them. Chapter 3 employs a Tobit model to analyse the AIS in both Kenya and Ethiopia, focusing on the adoption of forages. It identifies certain characteristics that increase the likelihood that a smallholder will adopt forages and highlights some areas of potential AIS failure. Chapter 4 uses social network analysis to analyse the informal network structures of farmers in Kenya and offers insight into how they can be used to make extension strategies more effective. Chapter 5 uses statistical models and network analysis to examine government created agricultural cooperatives in Rwanda and determine whether they are successfully generating social capital and therefore are a viable policy option for innovation promotion. Finally, Chapter 6 offers conclusions and recommendations based on the studies in the thesis.

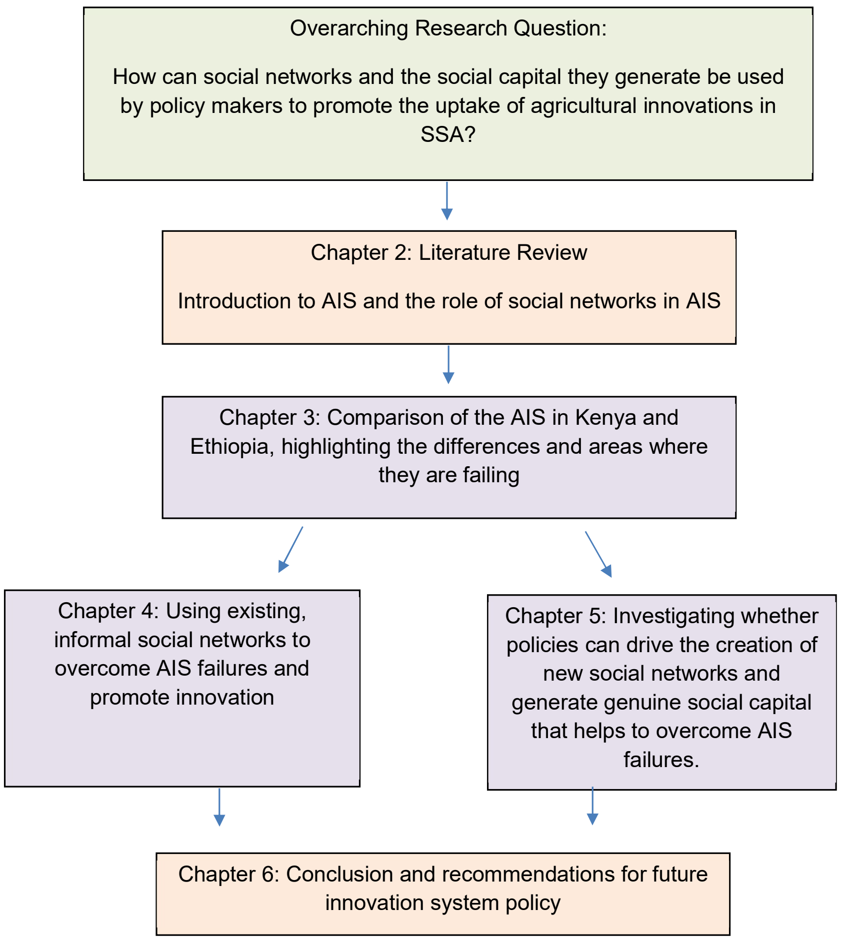

Figure 1.2: Schematic diagram of chapter contributions to the main research question

Chapter Two: Barriers to Agricultural Innovation: Systems and the Role of Networks

2.1 The adoption of agricultural innovations

Agricultural innovation studies occupy their own niche in innovation literature, diverging from the majority of innovation diffusion studies due to individual households, who have their own unique cultures and knowledge, often being the decision makers rather than firms (Feder & Umali, 1993). Consequently, economic theory related to individuals' decision-making behaviour, risk tolerance and socioeconomic contexts are often the focus in the agricultural innovation literature. This section of the thesis presents a short analysis of the main agricultural innovation paradigms followed by an in-depth review of the most recent paradigm, Agricultural Innovation Systems (AIS).

2.1.1 A brief timeline of agricultural innovation literature

Since the 1960's the literature on agricultural innovations has evolved dramatically, moving through multiple paradigms each with their own convincing narratives and counter-narratives (Hall, 2007). Klerkx et al (2012) categorise the four main eras or paradigms of agricultural innovation literature as: Diffusion of Innovations, Farming Systems, Agricultural Knowledge and Information Systems (AKIS) and Agricultural Innovation Systems (AIS). A summary of these approaches is shown in Table 2.1.

Table 2.1: The dominant approaches to agricultural innovations in recent literature

	Type of approach			
Characteristics of approach	Diffusion of innovations	Farming systems	Agricultural knowledge and information systems	Agricultural Innovation systems
Era	1960's	Started in 1970's/80's	From 1990's	2000's
Theory	Supply technologies through pipeline	Understand farmers constraints through surveys	Collaborate research and extension activities	Co-develop innovation with multiple actors
Scope	Productivity increase	Efficiency gains	Farm-based livelihoods	Value chains and institutional change

Innovators	Scientists	Scientists and extensions	Scientists, extensions and farmers	Multiple actors on the innovation platform
Role of farmers	Adopters / laggards	Sources of information	Experimenters	Partners, entrepreneurs, innovators
Intended outcomes	Technology adoption	Farming system fit	Co-developed technologies to fit livelihood systems	Capacities to innovate, learn and change

Source: Adapted from (Klerkx, et al., 2012)

Hall (2007) argues that these approaches are not mutually exclusive but are additive, with each broadening the perspective on which elements of the system are involved in the innovation process. The diffusion of innovation approach is based largely on Rogers' seminal work and focuses almost entirely on social systems and how communication and the mass media affect innovation diffusion (Rogers, 2003). In this paradigm both scientists and experts seek to promote technologies they deem appropriate for farmers in a top down, linear manner. Norman (2002) reasons that the economic tools that were being used to determine which technologies to promote in this approach were incorrect. They did not offer consideration to the fact that farmers may not prioritise profit maximisation and that they are relatively risk adverse. He suggests that this led to inappropriate and irrelevant technologies being recommended to farmers, who may have rationally opted not to adopt.

In response to limitations of the diffusion of innovation model, the farming systems paradigm emerged, marking a move from linear technology transfer to a more partnership-based model (Klerkx, et al., 2012). In this approach, farmers are viewed as sources of information that can provide an insight into what their objectives and demands are to ensure innovations fit (Norman, 2002). Both the farmers' socioeconomic and biophysical systems are considered to be important factors when designing and promoting innovations. The AKIS paradigm expanded the systems considered within innovation processes even further by adopting a 'soft systems' approach. Röling (1992) describes this as an approach where systems only exist as a result of the construction of those actors within them. System boundaries are arbitrary and wholly understood by the actors themselves, who have differing objectives and lived experiences. The focus of AKIS is to organise actors in a way which allows them to view themselves as embedded within systems with the intention of encouraging communication (Klerkx, et al., 2010). This approach is highly actor-centric, focusing on just the actors and processes in the rural environment and not on the market, private sector or policy landscape.

2.2 The Agricultural Innovation Systems paradigm

In 2006, the World Bank stated that the AIS framework 'appears to offer exciting opportunities for understanding how a country's agricultural sector can make better use of new knowledge and for designing alternative interventions that go beyond research system investments' (The World Bank, 2006). In the 14 years since this statement was issued, the concept of AIS has been used to both analyse and design many interventions in the innovation process (Pound & Conroy, 2017)

The AIS framework emerged almost in parallel to AKIS (Assefa, et al., 2009) yet offers a much broader perspective. AIS are defined as the 'network of organisations, enterprises and individuals focused on bringing new products, new processes and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge' (Hall, et al., 2006, p. 5). A diagrammatic framework for AIS is shown in Figure 2.1.

The framework in Figure 2.1 highlights the shift away from research-centred innovation towards a wider process in which research is only one element. Instead, AIS 'is about people, the knowledge, technology, infrastructure and cultures they have created or learned, who they work with and what new ideas they are experimenting with' (CGIAR, 2016). It is a multi-actor driven approach which has resulted in researchers who once found themselves at the top of the process embedded in a complex and broad system of processes and actors (Ananndajyasekeram, 2011). The AIS literature acknowledges that whilst many different actors and institutions are involved in the process, it can only truly 'take-off' when an innovation meets the demands of its principal user (FAO, 2020). Consequently, end users such as agricultural producers and agribusinesses are a core element of the innovation process.

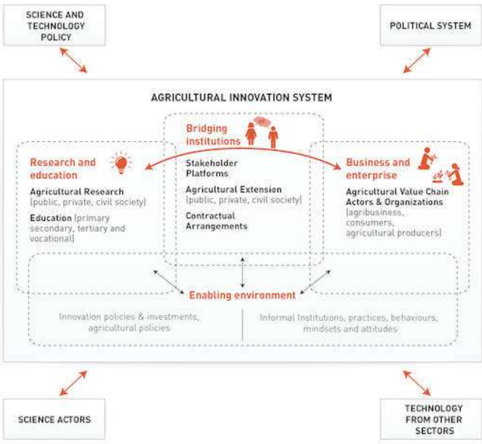

Figure 2.1: AIS conceptual framework

Source: Food and Agricultural Organisation (FAO, 2020)

A study by the World Bank highlighted several areas of importance for the effective operation of AIS. These included a focus on 'strengthening patterns of interaction across the whole range of actors involved in innovation' (World Bank, 2006). Hall (2007) argues that this would provide equal weighting to different sources of knowledge and would allow recognition of the fact there are multiple legitimate agendas which contribute to innovation in different ways. Bridging institutions, as shown in the centre of Figure 2.1 play a vital brokerage role in bringing together two or more actors and can act as mediators (Klerkx & Leeuwis, 2009). In the existing literature on AIS, the main two methods of bridging organisations are multi-stakeholder innovation platforms (MSPs) and extension services. The evidence of the success of multi-stakeholder platforms is mixed. Douthwaite and Hoffecker (2017) argue that they have the potential to offer a 'safe space' for discussion. However Schut et al (2016), Cullen et al (2014) and Kilelu et al (2013) both provide evidence that in reality the platforms can reinforce existing power dynamics and further marginalise smaller groups. In order for these platforms to work and be sustainable, the power dynamics need to be explicitly acknowledged and dealt with (Cullen, et al., 2014).

Extension services are another important form of bridging institution. However, their success is often dependent on whether the extension agents can successfully transition from their traditional role as teachers and instructors into new roles as facilitators in which the farmers are equal, participatory partners (Davis, et al., 2012). This novel approach to extension, often described as farmer participatory research (FPR) in the literature, encourages the co-evolution of innovations that meet the needs of farmers and benefits from their contextual and indigenous knowledge (Šūmane, et al., 2018). There is empirical evidence proving the effectiveness of such approaches to extension. In Ghana FPR projects for cocoa were created by the World Cocoa Foundation (Tsiboe, et al., 2016) and were focused on training, crop diversification and sustainable farmer practices. The projects were able to increase yields by 14% per hectare (Gockowski, et al., 2010). In a similar study in rural Kenya farmers experienced a 'change in perspective' which led to a 'significant shift in how they made sense of farming practices' (Duveskog, et al., 2011, p. 1539).

Whilst the relationship between researchers, farmers and businesses forms the core of the AIS framework, Hall (2007) argues that 'ultimately' being able to successfully organise interactions is dependent on what policies and institutional regimes exist. Pound and Conroy (2017) also note the importance of fast-moving and dynamic aspects of the external environment, such as the availability of communication technology and infrastructure, environmental concerns and the globalisation of agricultural productions, on the incentives, cooperation and behaviour of actors within AIS. The external environment therefore needs to be designed and understood in a way that supports effective collaboration. There is already evidence that by working together 'national agricultural research institutes, international research centres, farmers, and extension services have [already]… produced numerous research results that have led to increased knowledge and innovation in agriculture' (Asenso-Okyere & Davis, 2009, p. 2).

2.3 Where agricultural innovation systems fail

Due to the complexity of AIS, AIS practitioners tend to approach the issue of innovation diffusion by examining why and where the innovation fails (Klerkx, et al., 2012). Klerkx et al (ibid.) identify the seven key failures within innovation systems as: infrastructure failures, hard institutional failure, soft institutional failure, strong network failure, weak network failure, capabilities failure and market structure failure.

2.3.1 Infrastructure failures

The knowledge, physical and financial infrastructures all need to work effectively to support the innovation process. The knowledge infrastructure refers to the 'robust networks of people, artefacts and institutions that generate, share and maintain specific knowledge about the human and natural worlds' (Edwards, 2010, p. 17). Challenges to the knowledge infrastructure tend to arise as a result of diversity and 'cognitive distance' between the actors involved in the process which inhibits effective communication and cooperation (Klerkx, 2012). Homann and Rischkowsky (2001) and Van Asten et al (2009) both found that within SSA differences in the reference frameworks of farmers and scientists created difficulties in knowledge exchange. These issues are further aggravated by differences in education and communication abilities making it challenging for needs and deficiencies to be effectively communicated (Klerkx, 2012). In order for the knowledge infrastructure to function effectively, communication platforms must exist that allow for regular and easy communication between actors. In a study on coffee innovation platforms in Uganda, knowledge sharing was limited to mostly mobile phones and individual meetings and therefore did not provide deeper knowledge sharing opportunities between multiple diverse actors (Magala, et al., 2019).

The physical infrastructure such as roads, electricity, irrigation and transport, is vital for the dissemination of technologies and ideas (Lybbert & Sumner, 2012), the use of higher tech innovations (Douthwaite, et al., 2001) and access to markets (Stifel, et al., 2003). Spielman et al (2008) found that within SSA, many agricultural extension programmes were failing due to 'inadequate resources in terms of physical infrastructure' (Spielman, et al., p. 2). This can largely be attributed to the pervasive urban bias in government spending across SSA which has resulted in the under-development of rural areas (Ehui & Pender, 2005).

The financial infrastructure should offer effective microfinance, insurance and credit markets for farmers. These will provide the economic resources to invest in new technology and could also offer insurance against some of the economic shocks farmers face such as catastrophic weather events (Greatrex, et al., 2015). However, high levels of information asymmetry in the agricultural sector result in higher transaction costs and uncertainty which is then passed on to consumers through high interest rates and down payments (Ibrahim & Bauer, 2013). This often makes finance inaccessible to low-income smallholder farmers. This is evidenced in the micro-credit scheme created by the government of Cameroon aimed at encouraging innovation diffusion (Ndenecho & Akum, 2009). It sought to improve the purchasing power of rural populations through financing farm equipment and farm inputs. It largely failed due to the pre-conditions requiring a 10% deposit, evidence of viable productive assets as collateral and time-consuming bureaucracy. It has been widely accepted that the programme had little or no positive impact on technology adoption by farmers (ibid.).

2.3.2 Hard and soft institutional failure

The innovation systems literature views institutions as the rules and norms that govern behaviour, whether formal such as government policies, or informal such as cultural traditions (Hall, et al., 2003). If the formal rules are not correctly designed, they can inhibit the innovation process by creating perverse incentives and stifling creativity (Hall, et al., 2005). Informal rules can lead to issues such as increased corruption, cultural differences between researchers and farmers and a general aversion to participating in the innovation process (Hounkonnou, et al., 2012).

In recent years there has been an increasing level of acknowledgement that policies and regulatory frameworks spanning many domains can have an impact on innovation and therefore need to be coordinated. A focus on just research policy alone as a driver of innovation will fail to mobilise triggers, support structures and incentives (Hall, et al., 2005). In a study on the adoption of conservation technologies by farmers in SSA, it was found that insecure property rights were acting as a barrier. Farmers lacked the economic incentive to invest money on land which they rented, or did not have secured rights to, as they had no guarantee that they would be able to experience the full payback (Shiferaw, et al., 2009). Specific policy issues will be heavily context relevant, for example it was found that in Ireland, policies that facilitated and encouraged earlier inter-generational transfer of farms would help the innovation process as younger farmers tended to be more innovative (Läpple, et al., 2015).

Soft institutions have been described as 'implicit, unwritten rules or 'the way business is done'' (Amankwah, et al., 2012). These can take the form of customs, common habits, routines, traditions and norms (Kebebe, et al., 2015) and play a key role in decisions to adopt. In Ghana, several soft institutional failures that have been identified as impacting upon adoption included: a ritual of annual bush burning, the practice of land being skewed towards crop cultivation rather than livestock grazing, attitudes towards investment in animal husbandry and corrupt police (Amankwah, et al., 2012). These societal norms may make some innovations impractical or unacceptable for farmers to use or invest in (Klerkx, et al., 2012). Soft institutions also affect the way individuals interact with one another. Hounkonnou et al (2012) talk about 'the big man syndrome' that is present in Africa where a key figure seeks patrimonial power and treats all resources, both public and private, as personal assets that offer opportunity for patronage. In this type of network, farmers rarely receive a fair share of wealth and benefits, impacting on their income, ability and motivation to innovate.

2.3.3 Strong and weak network failure

Networks are vital to the innovation process. They can facilitate the transfer of knowledge horizontally between homogenous groups, but also vertically by allowing collaboration and cooperation between heterogeneous groups (Rogers, 2003). Network failures can occur when bonded networks are so tightly locked together that external, bridging links are not made which prevents beneficial collaborations. These are strong network failures. Weak network failures can also occur when actors within a network are not well-enough connected for meaningful and successful collaboration to occur (Klerkx, et al., 2012). Evidence of network failures is present throughout AIS. In a study of farming cooperatives in Senegal, Reed and Hickey (2016) found that the successful functioning of the cooperatives was partly dependent on whether key members were well-connected to broader 'innovation platforms'. These connections increased knowledge of innovations within the cooperative networks and facilitated innovation.

Weak network failures can theoretically be overcome through effective bridging organisations such as MSPs and extension services. However, evidence highlights that many MSPs, despite being a 'promising vehicle to achieve agricultural development impacts' (Hermans, et al., 2017), in reality can amplify both strong and weak network failures. In a study of MSPs it was found that that across the three SSA countries being analysed 'the collaborative networks … were dominated by supranational and national organisations whereas local organisations were mostly absent' (ibid, p.16). This creates disparities between stakeholder groups and increases the marginalisation of 'already disempowered groups and reinforc[es] power hierarchies to the detriment of smallholders' (Eidt, et al., 2020).

2.3.4 Capabilities failure

Actors within AIS are expected to work together and organise their capabilities across multiple levels and networks in a manner that mobilises and increases systemic innovation capacity

(Turner, et al., 2017). Capability failures can occur at all levels of the innovation systems; individuals or firms may lack the technological capability to operate new technology (Andreoni, 2011), the investment capability to buy new technology (Obiora, 2012) or research bodies may lack the capability to undertake agricultural research due to the volatile funding creating uncertain returns (Lee, et al., 2015). The consequence of capability failures is often the inability of firms or individuals to make the 'leap' to using new technologies (Woolthuis, et al., 2005). Therefore, capabilities such as learning potential, flexibility and resource endowments are important to the diffusion of innovations (ibid). Capability failure can be particularly harmful to technology adoption if farmers lack the human capital, such as training and entrepreneurship, to develop and initiate technology adoption strategies (Diederen & Meijl, 2002).

2.3.5 Market structure failure

The agricultural market structure forms the 'rules of the game' by determining incentives, prices and income (Mierlo, et al., 2010). The market structure can fail in multiple ways. Porto et al (2011) in their report for the World Bank highlighted how many of the agricultural supply chains are dominated by oligopolies who have market power over farmers, meaning they are able to keep more of the export profit, reducing income and investment incentives for farmers. Borremans et al (2018) identified another market structure failure within agroforestry systems. They found that the long rotation period of trees meant there was high levels of uncertainty in regard to how much products would sell for in the future. With many smallholder farmers having a short-term horizon for paying their bills, the uncertainty of future investment returns makes it unattractive to them.

The structure of the agricultural knowledge market has also inhibited knowledge exchange. Lamprinopoulou et al (2014) found that in their study on the Scottish and Dutch agricultural sectors, knowledge was treated as a private commodity which created information asymmetries and slowed innovation adoption. The farmers felt the information they were receiving was over-priced, biased and provided mixed messages whilst the suppliers found it difficult to identify and target their correct audiences. Attempts to find suitable partner's increases transaction costs.

2.4 Risk and uncertainty as barrier to agricultural innovation

Giddens (1984) argued that the structural environment that actors operate within acts as both a medium and outcome of their practices. Klerkx et al (2010) apply this theory to innovation practices and argue that the innovation environment exposes actors to high levels of uncertainty which they will try and reduce through their own limited ability. However, the innovation environment itself determines the limitations of an actor's ability to influence change. Understanding how AIS support or hinder farmers risk management strategies and perceptions of risks is therefore crucial in understanding the outcomes of their adoption decisions.

Farmers are constantly operating in a risky environment due to factors such as weather patterns and pests, which has provided them with an awareness of risks related to both expected returns and the variability of their returns (Chavas & Nauges, 2020). When faced with decisions regarding novel practices, farmers will make use of the information that is currently available to them to determine their riskiness (ibid). Smallholder farmers are often risk averse due to their dependence on agricultural for their survival, high levels of food insecurity, physical isolation and an absence of formal safety nets (Harvey, et al., 2014). It is therefore likely that they will have to perceive a technology as low risk if they are to adopt.

Despite the importance of uncertainty and risk in farmer's innovation adoption decisions, the vast majority of AIS literature maintains a macro-level perspective of systems and does not deal with the behaviour of individuals or their close networks. However, innovation systems need to support and provide effective risk management strategies if innovation diffusion is to occur (Brown & Osborne, 2013). Klerkx et al (2010) argue that this gap in the literature risks of not fully understanding the activities of innovating actors.

2.4.1 Uncertainties faced by famers in AIS

The main areas of uncertainty that are faced by farmers in the process of innovation adoption have been categorised in Table 2.2. Within AIS, these uncertainties can both inhibit the effective operation of AIS but can also be exacerbated by the existing failures discussed above.

Table 2.2: Types of uncertainty in AIS

Type of Uncertainty	Description	Source
Technological Uncertainty	• The characteristics of the new technology including yield increases and variability • Risk of failure of technology • The relationship between the new technology and existing infrastructure • What adaptions will be needed to the existing infrastructure • The possibility of better options becoming available in the near-future	(Klerkx, et al., 2010) (Sunding & Zilberman, 1999)
Resource Uncertainty	• Natural / environmental resources such as land quality, weather patterns and insects and disease including climate change • Human resources needed to use the innovation • Financial resources and access to financial support / credit	(Klerkx, et al., 2010) (Aimin, 2010) (Sunding & Zilberman, 1999) (Tey & Brindal, 2012) (Duong, et al., 2019)
Supplier Uncertainty	• Uncertainty about the reliability of suppliers claims • Dishonesty and corruption amongst extension workers • Long-term access to suppliers inputs	(Klerkx, et al., 2010) (Chukwuone, et al., 2006)
Political Uncertainty	• Governmental behaviour; policies, taxes, incentives, regulatory structure • Future regulations	(Klerkx, et al., 2010) (Aimin, 2010) (Sunding & Zilberman, 1999) (Duong, et al., 2019)
Market Uncertainty	• The volatility of market for agricultural goods and inputs • Transaction costs associated with access to market	(Aimin, 2010) (Sunding & Zilberman, 1999) (Duong, et al., 2019)
Social Uncertainty	• Social exclusion due to use	(Hall, et al., 2011)

2.4.2 Technological uncertainty

Farmers will always experience a level of uncertainty in regard to the characteristics of novel agricultural technologies (Sunding & Zilberman, 1999). The impact they will have on yield and yield variance can never fully be predicted in the contextual setting (Chavas & Nauges, 2020) and their compatibility with the existing infrastructure will not be fully known until the technology is used. Evidence suggests that farmers prefer technologies that minimise downside risks (Emerick, et al., 2016) and will therefore have a preference for those that offer a reduction in output failure (Falco & Chavas, 2009). However, many of the new technologies being promoted within SSA focus on yield maximisation and are more vulnerable to environmental and economic factors meaning there is increased risk of variability in output (Dawson, et al., 2016). Farmer's will also have a preference for technologies that they are certain will fit in the existing infrastructure due to their 'ease of use' (Aubert, et al., 2012). If they do not fully understand how the innovation operates and how compatible it may be, it may be deemed too risky to adopt.

Uncertainty in regard to technology characteristics has been amplified in SSA where evidence indicates that inappropriate technologies have been promoted to farmers, increasing distrust and the perceived risks associated with adoption. In Ethiopia, there has been widespread criticism in regards to a type of 'improved' seeds that were endorsed to small-holders and actually resulted in crop loss (Elias, et al., 2015) (Development Studies Associates, 2006) (Spielman, et al., 2010) .Whilst in South Africa there is evidence that the 'strategies used for disseminating GM maize technology were not participatory and relied mostly on the use of print media from GM seed companies whose primary clientele are literate commercial farmers.' (Kotey, et al., 2016, p. 71). This resulted in inappropriate cultivation practices being used which were not compatible with the natural and physical infrastructure. This reduced the long-term sustainability of the technology causing farmers to opt against prolonged use.

To reduce uncertainties and risks related to the technology characteristics, farmers need access to more information about the innovation and suppliers need to listen to farmer's needs, as encouraged within the AIS paradigm. Krishnan and Patnam (2013) argue that technologies need to be made 'specific to their surroundings' as many current technologies have been 'planned and implemented without the participation of the very people for whom they have been designed' (Belay & Abebaw, 2004, p. 149). There is general agreement in the AIS literature that farmer participation in the innovation process, through participatory extension activities and MSPs, is an effective method of reducing uncertainties (Pingali, et al., 2001). However, the practicalities of achieving decentralised and participatory extension services has proved challenging. In Ethiopia reforms aimed at decentralising extension activities were described as 'nominal' by Leta et al (2017, p. 11) as the national government controlled the planning, budget and the implementation of extension in local areas. The result was a technocratic approach with farmers being viewed as recipients and extension agents as providers (ibid, p.34) leading to the low uptake of technologies.

Across SSA there is also evidence of farmers lacking any access to extension agents or information that would help reduce technological uncertainties. A study on AIS within Tanzania found that 30% of extension agents had no means of transport to visit farms (Schut, et al., 2015), whilst a separate study found that 39% of Tanzanian sugar-cane farmers interviewed did not know where they could obtain agricultural information (Siyao, 2017). This was due to farmer training days being focused in urban areas which they could not access and extension agents being unwilling to travel to the farmers. In contrast in Malawi, 94.8% of rural farmers were aware of information sources but stated similar issues in regard to access and a lack of visits from extension agents (Phiri, et al., 2018). Comparable findings have been shown in other SSA countries including South Africa (Akpalu, 2013), Mozambique (Cunguara & Moder, 2011) and Kenya (Gido, et al., 2015).

2.4.3 Resource uncertainty

Managing resource uncertainties can be challenging for smallholders who are generally resource poor (Dixon, et al., 2004) and operate in unstable natural environments (Shiferaw, et al., 2009). Across SSA human capital resources are often strained due to poor health, largely related to the HIV epidemic (Apata, et al., 2016) and low levels of education (Amanor, 2009). This makes the availability and capabilities of the labour force uncertain creating risks in regard to investment returns. The natural resources that African smallholders have are unreliable due to previous bad management practices resulting in issues such as soil infertility and water scarcity (Marenya & Barrett, 2007). Climate change has also created unpredictability in weather patterns and increased the incidence and severity of extreme events such as floods and droughts (Jiri & Mafongoya, 2018). These factors have a massive impact on yield and create ambiguity around returns on investment.

Financial resources are also vital if famers are to invest in innovation. Due to low levels of liquidity amongst smallholders, credit and borrowing arrangements are often needed for the initial payment or deposit on new, expensive technologies (Marenya & Barrett, 2007). However, poor financial infrastructures can inhibit this by requiring high levels of down payments and difficult loan repayments, which given uncertainty in relation to yield and income, can be deemed too risky for smallholders (Sileshi, et al., 2012). A poor financial infrastructure will also reduce farmer's access to insurance which can ideally be used to buffer natural resource uncertainty and insulate against yield variance (Brick & Visser, 2015). The availability of insurance naturally reduces the risks farmers face as some losses will be borne by insurance (Meyer, 2015).

Resource risks such as these require farmers to have the capabilities to interpret the strategic risk and produce risk management strategies (Diederen & Meijl, 2002). When they are unable to do this, the increased level of income risk may make investment and adoption in new technologies unappealing. A study on small-holder farmers in Bangladesh found that farmers who were engaged in education training where more willing to change farming practices to cope with climate risks (Aryal, et al., 2019). Similar findings have been confirmed in other studies (Abid, et al., 2020) (Deressa, et al., 2009).

2.4.4 Supplier uncertainty

AIS are dependent on the cooperation and participation of both farmers and suppliers in the co-evolution of new technologies. If farmers are not sure about a supplier and whether the claims they make about their innovations are trustworthy, they are unlikely to adopt it (Best, et al., 2005). Lyon (2000) notes that actors take in tacit information in regard to other actors' trustworthiness throughout knowledge sharing interactions. It is therefore crucial that the knowledge infrastructure creates an atmosphere of trust.

Supplier uncertainty is exacerbated by network failures as 'farmers consider it to be much riskier to adopt innovations coming from socially distant outsiders' (Hoffmann, et al., 2007). With network failures, AIS lack the connections, which have been referred to as 'cross-cutting ties' (Paxton, 1999) that form the vital bridges that reduce social distance. Innovation networks which are 'created for the deliberate purpose of enabling innovation rely on social capital and trust to enable people in groups to work together effectively' (King, et al., 2019). When strong network failures occur it can produce an 'us-versus-them' mentality which results in high trust between members, but high distrust of outsiders (Coffe & Geys, 2007), meaning there is too much risk and uncertainty in trusting those outside their bonded network making it hard for information to jump the gap.

Uncertainty and a lack of trust in supplier claims are prevalent in extension systems across SSA where relationships between farmers and agents can become strained. Stevens and Ntai found that at their study site in Lesotho the 'technical subject and extension support… [was] inadequate' (2011, p. 111). Similarly, Belay and Abebaw stated that in Ethiopia the extension agents 'qualification and communication skills left a lot to be desired' (2004, p. 139) and that '46 per cent and 32 per cent of the respondents pointed out respectively extension agents' lack of experience in using extension methods' (ibid, p.159). However, they find that this opinion is not reflected amongst the extension officers themselves who believe that that 'they have told farmers what to do, but the farmers are just too stupid to understand' (ibid p.18). These issues are also amplified by the failures of promoted technologies and methods to meet the needs of farmers.

2.4.5 Political uncertainty

The policy and regulatory framework that smallholder farmers operate within can create an environment of uncertainty for farmers if not properly managed. Within SSA agricultural policies have been volatile and this has partly been blamed for the region missing out on the 'green revolution' experienced by Asia. Jayne and Rashid (2013) argue that policies to support input subsidies across SSA resulted in higher outputs, which led to further policies to support farm prices including changes to international trade policies. These constant changes to agricultural policies created uncertainty for farmers who were facing increasingly volatile prices. In the specific context of Nigeria, it was found that there was 'high apathy on the part of the farmers regarding anything from government because nobody knows how long such may last … [and] erratic import policies characterized by frequent changes in both import tariffs and quantitative import restrictions thus creating much uncertainty for producers' (Enete & Amusa, 2010).

2.4.6 Market uncertainty

Decisions on agricultural production are made in advance before the market price for the final output is known. As agricultural markets are typically volatile, there is a high amount of uncertainty regarding how much money a smallholder will get for their produce (Aimin, 2010). This uncertainty can be particularity challenging for smallholders who suffer from size-related disadvantages in the market and therefore have limited negotiation and price setting power.

Market uncertainty can also be exacerbated by infrastructure failure, for example a study on rural villages in Nicaragua examined how investment in a bridge which allowed access to markets even during periods of flooding saw farmers spent up to 60% more on inputs such as fertilizer and pesticides and farm profits increased by 75% (Brooks & Donovan, 2020). In rural locations, where many smallholders tend to live, poor physical infrastructure can therefore lead to uncertainty over market access and an increase in transactions costs, all of which perpetuate market uncertainty (Magesa, et al., 2014).

2.4.7 Social uncertainty

Soft institutions create social norms by which most farmers abide. Failing to follow certain social norms, for example by using a new, unknown agricultural innovation, can result in social exclusion and non-monetary penalties (Kevane & Wydick, 2001) (Platteau, 2000). Some social norms in SSA have high levels of cultural significance and therefore going against them may be controversial and result in hierarchical community figures refusing to accept certain practices and those who use them (Moser & Barrett, 2006). A farmer may therefore be uncertain whether adopting a new farming practice will be against current social norms or may be unsure of any social sanctions that will occur from its use and will therefore opt to not adopt. Other social norms may promote ideas of 'good citizenship' and 'orderliness' that encourage conformity and prevent farmers from thinking creatively or acting independently (Dakhli & Clercq, 2004). In general, if group social norms conflict with the interests of wider society, they can be detrimental to development (Knack & Keefer, 1997).

2.5 The importance of social capital and networks in AIS

Social capital, defined as the positive product of human interactions and relationships, is widely identified as a factor in economic growth and development due to it, amongst other things, reducing transaction costs, facilitating the transfer of information and enhancing trust (Rijn, et al., 2012). One of the many channels through which social capital can promote development is through enhancing the adoption of new agricultural technologies (ibid.). The relationships between actors throughout innovation systems are vital to reducing uncertainties and ensuring appropriate technologies are developed. Despite the difficulties in developing a unified definition of social capital, it is widely accepted that social networks and the personal relationships that form them are at its core (Sato, 2013).

The importance of networks in innovation diffusion has been acknowledged since the first innovation paradigm popularised by Rogers (2003) who focused on 'diffusion networks' and their ability to transfer information between potential adopters. As the scope of innovation system studies expanded, so did the importance of social networks within these systems. Within the AIS era, networks are considered central to the adoption process as they allow actors to 'interconnect…to exchange and generate new innovations for increasing farmer productivity' (Weyori, et al., 2016).

2.5.1 Social Networks

The literature on social networks has developed dramatically over the past decades with Putnam (2000) and Burt (2004) developing frameworks through which the functioning of networks could be analysed. These frameworks are Putnam's bonding and bridging social capital and Burt's structural holes theory.

Portes and Landolt argue that networks can be either open or exclusive (1996). The openness that they refer to is captured in Putnam's description of bridging social capital which he states as occurring when 'a society that relies on generalised reciprocity is more efficient that a distrustful society… Trust lubricates social life' (Putnam, 2000, p. 135). The connections, or 'cross-cutting ties', across society (Paxton, 1999) form 'outward looking [networks that] encompass people across diverse social cleavages' (Putnam, 2000, p. 22). Callois and Aubert (2007) argued that 'bridging social capital is essential for bringing new ideas and opportunities'. It is likely to improve generalised trust across society, encouraging groups to successfully work together (Crescenzi, et al., 2011). The structural holes theory developed by Burt (1992) offers a similar insight into the importance of ties that bridge two separate networks but adopts a greater focus on the advantages of the actors in the 'bridging' position. A structural hole refers to a gap between two networks or individuals who have complimentary information. Kleinberg et al (2008) state that 'through intermediation [individuals] can broker the flow of information and synthesize ideas arising in different parts of the network' (p.284). In essence, an actor who positions themselves as a tie between the two networks is able to exploit the hole and use the information for their own gain. Burt (1992) argues that those who bridge the holes are often entrepreneurs that are seeking out new information and that these individuals are able to transform the network structure. Therefore, in a similar manner to bridging social capital, the theory of structural holes highlights the benefits of having networks that are open and connected to other networks in the innovation process and for economic growth.

Bonding social capital is said to represent the exclusivity or 'dark' side of social capital, although positive externalities are also generated from it. In Putnam's work, bonding social capital consists of 'inward looking [networks that] tend to reinforce exclusive identities and homogenous groups' (2000, p. 19). Commonly used examples of bonded networks often include the Mafia (Svendsen, 2006) and terrorist groups (Asal, et al., 2014) (Bramadat, 2005). Bonded networks such as these share a collective orientation with restricted external information which can reinforce a sense of common identity and purpose (Svendsen, 2006). Densely connected networks can inhibit information sharing which has negative impacts on innovation and economic growth. Positive effects can also arise from membership of a bonded network. Wilkinson (1996) argues that for those within the closed networks, bonding social capital provides social and material support and can act as a buffer during hardships. This led Putnam to describe bonding social capital as important for helping people get by, as opposed to bridging which helps people get ahead (Putnam, 2000). It is this ability of bonding social capital to help people in their day-to-day lives which has led researchers to believe it is more prevalent in poorer communities.

In a similar manner to structural holes theory and bridging social capital, Burt offers a complementary assessment of bonding social capital which he refers to as network closure (Burt, 2000). Network closure is described as a 'network in which everyone is connected such that no one can escape the notice of others' (ibid, p.351). A consequence of these tight-knit networks is the increased ability to impose sanctions between members, causing individuals to trust one another (Burt, 1992). These conditions can also increase the cost of defection through ostracising individuals from the group and its benefits if they fail to cooperate. Individuals may therefore be coerced into behaving cooperatively even if it is not their preferred outcome (Gargiulo, et al., 2009).

The concept of linking social capital was added to Putnam's framework later by Szreter and Woolcock (2004) who describe it as the 'norms of respect and networks of trusting relationships between people who are interacting across explicit, formal or institutionalized power or authority gradients in society' (ibid., p.655). The distinct difference between bonding and bridging social capital is that they refer to horizontal ties whilst linking addresses the vertical ties between those of different social strata (Woolcock, 2001). Putnam (2004) argued that if linking is to be regarded as a form of social capital, it may be important to distinguish been responsive linking, which produces more social trust and unresponsive linking, which is negatively correlated with social trust, citing the example of the negative relationship between frequency of contact between citizens and local officials in Italy. Some researchers view linking social capital to be a subset of bridging social capital (Claridge, 2018) in that it refers to a tie between two separate networks

2.3.2 Social networks in AIS

At the very core of AIS is the communication and collaboration between farmers, researchers and suppliers. Promoting strong and effective social networks that span social strata is therefore vital to their functioning. The broad systems approach used in AIS also highlights the importance of all the social systems that actors participate in, including formal structures such as the MSP, or informal structures, such as village and kinship networks. Ahlerup et al (2009) argue that social capital can be a substitute for formal institutions, meaning that the social networks within AIS can play a crucial role in overcoming some of its failures. In developing regions this is particularly important as formal institutions tend to be weak. Networks are also important in the transfer of information, meaning they play an essential role in increasing knowledge and awareness of technologies therefore reducing information asymmetries and risk perceptions. Burt notes the importance of certain individuals who act as 'brokers who carry information across the social boundaries between groups' (Burt, 1999, p. 37).

Evidence of the success of social networks in facilitating the diffusion of innovations and overcoming AIS failures is discussed below.

2.5.4 Bonded networks

Although Putnam and many other researchers view bonding social capital as a 'negative', bonded networks can result in increased support, the sharing of trusted information and cohesion within communities (Bodin & Crona, 2009). These networks are highly important within AIS as they offer opportunities for tacit knowledge sharing, risk sharing and the provision of material support between members. Bonded networks are therefore often encouraged and sometimes forcibly created by governments, NGO's and other development actors with the aim of using the social capital to promote community-driven development (Portes & Landolt, 2000). In terms of agricultural development, the existing literature tends to focus on two different forms of bonded networks. The first are formalised, local level famers organisations (FO) such as agricultural cooperatives, that have an established leadership structure and clear mandate, and the second is informal groups, often formed without specific agricultural objectives, where arrangements such as causal loans or resource management can result in improved agricultural outcomes.

There is no single blueprint for how FOs are founded, how they operate or what their objectives are. FOs may help small-scale producers by increasing access to markets, credit and extension services whilst they may also focus on training and skills in production, marketing and entrepreneurship (Bizikova, et al., 2020). Some FOs can emerge as a result of government policy, as evidenced in Rwanda where the government views cooperatives to be a ‘key vehicle’ in agricultural development (Verhofstadt & Maertens, 2014). Others emerge as a result of local-level community action, in which existing relationships or networks are formalised, often with leaders and regular meetings (Sedana, et al., 2014). FO’s are usually membership organisations that require farmers to meet formalised criteria, such as membership fees or participation in various activities, and sometimes informal criteria such as gender, ethnicity and religion (Stockbridge, et al., 2003). The informal criteria increase levels of homogeneity which is related to greater amounts of bonded social capital between members (Lang & Fink, 2019). When FO’s are created externally, potentially by government bodies or NGO’s, it is important they build upon a base of genuine social capital and relationships in existing networks as often attempts to create such networks, which Portes and Landolt (2000) describe as ‘social engineering’, can fail to create any solidarity between members meaning the networks fail (ibid).

Unlike FO’s, the informal bonded networks discussed in the literature are not always solely or intentionally agriculturally focused. Instead, they often arise through members self-organising themselves into small groups with varying motivations. In India, these groups have taken the form of self-help groups (SHG’s) in which individuals, often women from similar socioeconomic backgrounds, group together to apply for loans from development actors (Kumar, et al., 2019) or to contribute to a common pot of money from which members could then borrow from (Raghunathan, et al., 2019). Similar informal finance groups exist in Kenya called ROSCAS (rotating savings and credit associations) (Anderson, et al., 2003). Church groups, families and neighbours are also included in this category and can have a significant impact on information transfer, risk perceptions and behaviour (Campbell, et al., 2013). Informal networks tend to have high levels of social capital because members will know a great deal about each other's trustworthiness and are closely connected, meaning any default on payments or similar un-cooperative action can be punished through social sanctions (Anderson, et al., 2003).

Zhang et al (2019) argue that membership to FOs, such as agricultural cooperatives, can form a part of farmers risk management strategies, allowing them to engage in higher risk/return activities. Kaganzi et al (2009) found that they allow farmers meet the requirements for quantity, quality and frequency of supply which due to asymmetric information they would not be able to do alone. Similarly, FO's may help in facilitating contractual arrangements with buyers which can be an entry point to large markets for many farmers (Akul, et al., 2018). This helps reduce uncertainty in regards to market prices and transaction costs. Eboh (2002) made a similar argument for informal groups claiming they can 'resolve problems of information asymmetry, transaction costs and the related risks'. Simply being a member of informal networks that do not specifically focus on agriculture can provide individuals with the social capital to aid their economic development and overcome uncertainty. In a study on Ethiopian farmers it was found that the social capital amongst members of the same 'Iddir', which are collective funeral funds, meant that they helped each other out during livestock loss, crop failure, illness of a family member and/or fire loss (Husen, et al., 2017). However, the same study suggests that membership of such groups may require cash or similar contributions, which diverts investment away from technology adoption (ibid).

As discussed earlier, farmers are often poorly served by the financial infrastructure within AIS facing high interest rates, unreasonable down payments, low levels of trust in the organisations and high levels of bureaucracy. Many overcome this failure by joining informal credit networks, accessing credit through the cooperative or grouping together to access credit from more reliable NGO's or government institutions. In Pakistan, informal rural credit markets arise as a component of broad social networks and are rarely the sole purpose of the relations (Manig, 1990). Access to short-term loans resulting from established relationships developed through agricultural marketing increased farmers investments in agricultural inputs (ibid). In the Philippines, zero-interest informal loans were likely to be offered by other family members if economic shocks occurred, allowing risks to be shared amongst those in the same network (Fafchamps & Lund, 2003). Providing access to credit is also a traditional role of FO. Badiru et al (2016) found that cooperative societies are the second most important source of credit to smallholders, outside of their informal networks and saving groups. The credit can come from external sources but passes through the cooperative itself or from the cooperative members pooling their resources (Ofuoku & Urang, 2009). Accessing credit through cooperatives farmers are able to obtain more reasonable terms and have greater trust in the lender.

2.5.5 Network bridging

In order to ensure that bonded networks effectively promote innovation diffusion and help to overcome some of the AIS failures and uncertainties there needs to be sufficient bridging social capital present. Knack and Keefer (1997) argue that when there is a high level of bonding social capital, without bridging capital there may be a limited flow of inputs or information beyond local networks, which is important in innovation diffusion. It is therefore preferable to find a balance between bonding ties in networks to ensure that trusted information is readily shared and bridging ties to ensure new ideas enter bonded groups (Ohno, et al., 2010). However, in developing countries linkages between various networks and actors tend to be sporadic and fragmented (World Bank, 2006) which results in lower levels of bridging capital.

The bridging institutions in AIS, such as MSP, innovation platforms and extension services are deliberately used to create the bridging links that are needed to create and promote innovations. These formal bridging networks have mixed success due to various factors discussed in previous sections of this review, such as the power dynamics, rural settings and poor-quality information. The broad systems approach used in AIS literature supports the idea that bridging links need to exist outside of direct knowledge infrastructure and need apply to a broad range of tasks and interactions that all indirectly affect innovation decisions (Klerkx, et al., 2012).

A relatively new approach to forming bridging links in AIS that has emerged has been the use of intermediaries or brokers (Kilelu, et al., 2011). These intermediaries or brokers can hold various roles which are often disputed in existing literature due to a lack of conceptual agreement on what is an ‘intermediary’ (ibid..). Hellin’s (2012) review of agricultural extension services in Mexico investigated the importance of network brokers in providing support for village networks to engage with other actors in the innovation system. In his study an NGO acted as a ‘systemic intermediary’, where they facilitated linkages and interactions rather than focusing one-on-one relationships (Klerkx, et al., 2009). To achieve this they trained individuals, who had been selected by the other villagers, in accessing information and building up their capacity to engage. These individuals would then act as an ‘entrance gate for external intervention into the rural community’ (Moumouni, et al., 2009, p. 311). This form of brokering allows strong network failures to be overcome, increases the capabilities of small networks and due to the individual being selected by their own community, can help reduce social uncertainty and overcome soft institutional failures.

Bridging links are also important in overcoming weak network failures as they encourage productive relationships to develop between various AIS actors. They can also reduce many uncertainties as end-users are able to develop a relationship with suppliers and therefore view them as more trustworthy and they may be able to directly influence innovation design, so they are more certain on its characteristics. However, bridging institutions and the network links they help create must be inclusive and put the needs of smallholders at their core if they are to be successful.

2.6 Conclusion

This literature review has explored the various elements of AIS, how they can fail and the uncertainties that farmers within them face. It has also highlighted the importance of social networks within AIS and their ability to help overcome failures and promote innovation diffusion. The rest of this thesis will use the AIS framework to assess innovation adoption in East Africa.

Chapter 3: An innovation systems approach to understanding forage adoption intensity in the dairy systems of Kenya and Ethiopia.

3.1 Summary

Agricultural Innovation Systems (AIS) will function differently across different countries and contexts. As a result, the failures and uncertainties that exist within AIS also differ and policies used to improve the innovation system will need to consider this. This thesis chapter therefore explores the AIS of Kenya and Ethiopia to help form an understanding of their weaknesses and how social networks can be used to overcome them.

This chapter specifically focuses on the innovation systems related to the adoption of cultivated forages in smallholder dairy systems as they offer a cost-effective way to increase the productivity of livestock resulting in higher milk yields. Both the Kenyan and Ethiopian governments have stated an ambition to increase the use of forages in their dairy sectors. However, their existing policies have failed to produce widespread results with forage uptake remaining low and many farmers still experiencing regular feed shortages and low yields. There is no clear consensus as to why forage cultivation is so low and existing research tends to focus on barriers to adoption and does not provide insight into the wider innovation environment. To fill this literature gap, this chapter uses an AIS lens to analyse village level data collected from a 2015 study across Kenya and Ethiopia. The results highlight the institutional differences between Kenya and Ethiopia and the diversity of their dairy systems, emphasising the importance of pluralistic innovation systems with strong bridging links between actors and informal relationships and information sharing between farmers.

3.2 Introduction

Livestock innovations such as improved forages have the potential to increase dairy yields, resulting in higher income and better nutrition for smallholders. With food security and poverty being pressing issues across sub-Saharan Africa (SSA), the promotion of cultivated forage use amongst smallholders has been included in the national agricultural development strategies of both Kenya and Ethiopia (Ericksen & Crane, 2018) (Turner, et al., 2019). Incorporating forages into livestock diets has been identified as one of the most important variables affecting milk yields (Osele, et al., 2018) and can be a cost-effective and easy option for resource poor smallholders to improve their productivity (Wambugu, et al., 2011). The policies aimed at increasing forage use can therefore result in improved food and nutrition security, both of which are key priorities for the Kenyan and Ethiopian governments (Ramos, et al., 2020) (Tura, 2019) and relate to the second Sustainable Development Goal of achieving zero hunger by 2030. Despite this, the uptake of forages has remained low with the underlying reasons not being fully understood. The majority of previous studies have provided insights into technology adoption constraints linked to household and technology characteristics but have not given sufficient attention to the wider context that enables innovation processes (Kebebe, et al., 2015). Studies that have looked at the wider context note, for instance, the importance of capacity building across the whole innovation system and livestock value chain (Ayele, et al., 2012). The Agricultural Innovation Systems (AIS) paradigm looks at innovation with a broad lens, capturing the wider institutional environment and the actors within it. This study therefore uses an AIS lens to analyse and understand what aspects of innovation systems are influential in smallholders' decisions to grow forages to feed their dairy livestock. These results can then be used to inform the creation of effective forage policies in the future.

The AIS paradigm views innovation as a broad process that 'is about people, the knowledge, technology, infrastructure and cultures they have created or learned, who they work with and what new ideas they are experimenting with' (CGIAR, 2016). Despite the importance of a range of actors and institutions in the process, an innovation can only truly be scaled up if it meets the demands of the end-user (FAO, 2020). Effective innovation systems are therefore usually demand-led and responsive to the users' needs (Aerni, et al., 2015). Smallholder farmers are a specific category of end-users embedded within AIS. They are a complex group with many competing objectives when making decisions regarding their agricultural practices (Adolph, et al., 2020). They are often required to make judgements between long- and short-term goals, have their own social, environmental or economic aims and are faced with differing risk perceptions and beliefs (Adolph, et al., 2020) (Buyinza, et al., 2020).

Within Kenya and Ethiopia, smallholders produce 56% (Odero-Waitituh, 2017) and 97% (Getabalew, et al., 2019) of milk respectively. They are not a homogenous group, as highlighted by the variety of dairy systems that exist both between and within countries. In Ethiopia, three distinct dairy systems have been identified; urban, peri-urban and rural (Tegegne, et al., 2013). In rural dairy systems, smallholders are more isolated, depending heavily on public actors for their farming information (Tefera, et al., 2010). They rely on natural pastures and crop residues for feed and are generally less market orientated compared to their urban counterparts (ibid.). Increasing proximity to urban areas is associated with more intensive dairy systems that are more reliant on purchased and backyard fodders and crop residues (Tegegne, et al., 2013) (Tefera, et al., 2010). Kenyan dairy systems are also categorised based on their proximity to urban areas (Nyokabi, et al., 2021) and in a similar vein to Ethiopia, smallholders near urban centres tend to have more intensive feeding practices, higher market orientation and access to a wider range of actors (Njarui, et al., 2016) (Odero-Waitituh, 2017). However, in Kenya there is a long tradition of growing local Napier grasses for stall feeding (Duncan, et al., 2016), which is common even in the less intensive, rural areas. One of the key differences between both countries' dairy systems is how easily farmers can access markets to sell their milk which has been identified as determinant of dairy intensification (Lee, et al., 2020). In Kenya, high demand for milk means buyers compete for it, resulting in a developed milk collection grid that is accessible to remote farmers. Kenya also has a better infrastructure when compared to Ethiopia, which reduces transaction costs and allows even the most rural farmers opportunities to market their milk (Staal, et al., 2008) . In Ethiopia, farmers tend to sell more diverse crops and milk markets tend to be focused around areas that have the best infrastructure (Lee, et al., 2020). This means that farmers have less opportunities to market their milk, which is associated with less intensive dairy practices.

Despite smallholders producing the majority of food in Kenya and Ethiopia, evidence suggests that they experience food shortages around 2 and 7 months a year respectively (Shikuku, et al., 2017). This has largely been attributed to low agricultural productivity and current ineffective forage adoption policies have failed to overcome this (Creemers & Aranguiz, 2019) (Gebremedin, et al., 2003) (Njarui, et al., 2017). To address this and assist with the creation of future policies, a better understanding of forage innovation systems and their interaction with dairy systems is needed. This study therefore seeks to add to this area of literature by answering the research question 'what do the characteristics of dairy producing villages in Ethiopia and Kenya tell us about the forage innovation systems in each country?'. The data used in this study was collected in 2015 by the International Livestock Research Institute (ILRI) and was gathered at the village level. Using village level data allows for the study to focus on the wider contextual factors related to forage innovation systems and not solely on farmer characteristics. In line with the AIS concept of innovation and adoption being a continuous process, this study does not treat adoption as a binary outcome. Instead, it uses an adoption intensity variable that reflects the continued decision-making process. This study will initially provide a conceptual framework in which agricultural innovation systems in the smallholder context are discussed in depth. It will then present the data and methodology used for the study, followed by the results of the data analysis. The final sections form a discussion of the data analysis results and their policy implications.

3.3 Conceptual Framework

3.3.1 Agricultural Innovation Systems

AIS focus on the collective nature of innovation, emphasising the importance of co-evolutionary processes that involve a range of actors, organisations and institutions. These components of AIS interact and adapt over time, creating a complex and non-linear innovation process. The process is not always straightforward and tensions and differences between actors can negatively affect outcomes. Figure 3.1 below shows a simplified conception of how the elements of AIS interact.

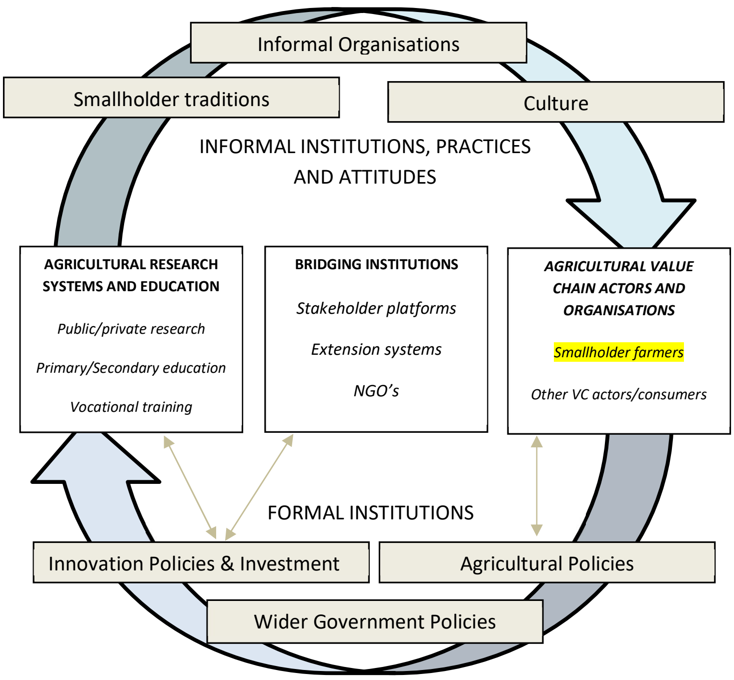

Figure 3.1: Agricultural Innovation Systems, adapted from Aerni et al (2015)

The outer ring in Figure 3.1 represents the enabling environment where the rules and norms that govern behaviour and interactions within AIS are set. Formally devised rules, such as regulations, policies and laws make up the formal institutions. To be effective, various types of formal institutions need to work together to support positive innovation behaviour. In the context of Kenya, the devolution of certain dairy policies to county governments has led to dairy-specific policies and regulations being scattered, making it difficult for a single coherent and enforceable approach to dairy development to be identified (Rademaker, et al., 2016). This has acted as a barrier to innovation, as it is risky, costly and complicated to operate in a confusing environment. In certain circumstances, devolved dairy policies could have the potential to allow for local contexts to be better considered in policy making and create a positive environment for innovation. However, such an approach needs to be designed in a way that is clear, understandable and coordinated. The role of formal institutions has been argued to expand beyond the policies and regulations that directly relate to innovation, research and development (R&D) and information dissemination. Brooks and Loevinsohn (2011) found that they also need to set the conditions for an aware citizenry who can express themselves and hold elected officials to account (ibid, p.196). If designed correctly, formal institutions can promote and facilitate demand-driven innovation, however if poorly designed they can hinder it (Kebebe, et al., 2015).

Informal institutions are the unwritten rules, such as the norms of behaviour and codes of conduct, that are self-enforced by people within the community. These informal institutions can be important in governing the use of communal resources, such as grazing lands for livestock, by creating rules around their usage (Yami, et al., 2011). Informal institutions can also take the form of informal groups that fill in the ‘vacuum left by the lack of formal institutions’ (Odera, 2013, p. 1). For example, Iddirs are an informal risk-sharing insurance institution in Ethiopia that were originally set up to provide mutual aid for burials and funerals. They expanded to provide loans for members when they experience economic shocks. Iddirs are built on a foundation of trust and reciprocity, resulting in them also being a reliable channel of information for farmers (Belissa, et al., 2019). When information regarding agricultural practices is communicated via Iddirs, adoption rates are higher as farmers trust the information (ibid.). A high amount of context specificity can therefore help to create appropriate solutions to innovation problems (Tefera, et al., 2010).

The centre of Figure 3.1 represents the organisations, actors and networks that contribute to the innovation process. This study focuses on smallholders, who are a specific type of agricultural actor, as the end user. Smallholders are not a homogenous group and have individual needs, motivations and risk attitudes, which need to be accounted for when designing innovations. For AIS to be effective in facilitating diffusion of novel technologies, they should be collaborative and allow smallholders to share their knowledge and help co-design context-appropriate innovations. This collaboration process can be facilitated and supported by bridging institutions, such as extension services and stakeholder platforms, that help to actively embed smallholders in the wider agricultural system. Collaboration between public and private actors that operate within AIS is important to success. A study for the World Bank on how AIS can be strengthened overall found that a lack of interaction due to 'deep-rooted habits and practices' (Hall, 2007, p. 18) was key reason for their failure. Private actors, such as market actors, are often responsible for the creation of technologies due to their search for value-added and market opportunities (Hall, 2007) (Rajalahti, et al., 2008). Public actors, such as public research institutes and the state, usually contribute to the innovation process in the setting of standards and regulations (Rajalahti, et al., 2008) and through the creation of policies and investments.

3.4.2 Forage and Dairy Systems

Forages can be a valuable feed source for dairy livestock and offer a cost-effective way to improve dairy yields and smallholder productivity (Wambugu, et al., 2011). These productivity increases are linked to better nutrition and improved food security. One study found that mixing local Napier grasses with Brachiaria, a 'climate-smart crop', resulted in a 15-40% increase in milk production and increased the average daily body weight gain of cattle

(Ghimire, et al., 2015). Another study on the use of Calliandra as a substitute for dairy meal in Kenya and Uganda found that if 500 shrubs were planted, by the second year a farmer with one dairy cow could see their income increase by about 20% per year (Place, et al., 2009). It is claimed that 500 shrubs could easily be accommodated by a typical 1.5 ha farm without replacing any existing crops as Calliandra can grow on 'terrace edges or bunds, along internal fields and homestead boundaries, and in Napier grass plots' (ibid, p.10). Despite the evidence of the benefits of feeding livestock forages, their uptake has remained low in both Kenya and Ethiopia (Gebremedin, et al., 2003) (Njarui, et al., 2017).

Within Ethiopia, public sector actors are heavily involved in the promotion of forage use and its related services. Agricultural extension services are almost exclusively provided by the government and have been criticised for failing to empower farmers due to a lack of 'actionable strategies' making them unable to respond to user needs (Gebremedhin, et al., 2006) (Tefera, et al., 2010). In a similar manner, rigid mandates have meant the heavily government-funded research sector has failed to focus on non-technical issues, limiting the impact forage research has had on dairy development (Järnberg, et al., 2018) (Kebebe, et al., 2015) (Tefera, et al., 2010). These barriers to innovation are further exacerbated by the high levels of bureaucracy that prevent private sector actors entering into the system (Aranguiz & Creemers, 2019). Cultivated forages are not commonly used in Ethiopian dairy systems; instead in the rural and peri-urban areas smallholders tend to rely on natural pasture grazing or crop residues (Tefera, et al., 2010) (Tegegne, et al., 2013). In these areas, informal institutions that oversee the collective governance of the communal grazing lands are often present (Yami, et al., 2011). In urban areas, restricted land space has meant purchased concentrate and roughage feed are the predominant feed source (Duguma & Janssens, 2016).

Within Kenya, the government has supported a liberalised approach to dairy, leaving many elements of the sector to be dictated by market forces and private or non-government actors (Kaitibie, et al., 2010). This has left gaps in the formal infrastructure, particularly in access to finance as many private lenders see smallholders as too high risk which acts as a barrier to on-farm investments. As a result, ‘NGO’s and donors [are] … expected to inject … into cooperatives … credit, grants and material support’ (Ministry of Finance and Planning, 2002, p. 29). These gaps in the formal infrastructure have also led to an increase in informal institutions such informal savings and credit groups (Wilkes, et al., 2019). Some parts of the Kenyan agricultural sector experience, and benefit from, a higher level of state involvement. For example, formal forage seed systems are governed by well-developed and structured legal and regulatory frameworks (Creemers & Aranguiz, 2019). As a result, the Kenyan forage seed sector has government research centres, seed certification schemes and has seen improvements in seed packaging and production (ibid.). However, due to a large proportion of planting materials and seeds being exchanged informally between farmers, the positive effects of forage seeds regulations are constrained as they tend to be mostly focused on large formal organisations (Maina, et al., 2022). There is also limited evidence of success in the wider dairy policies as they are split between different central government organisations and devolved administrations resulting in them being ‘scattered’ and hard to enforce or regulate (Rademaker, et al., 2016).

The use of cultivated forages within Kenya is generally higher than Ethiopia, mostly due to a long tradition of using local Napier species to feed livestock (Duncan, et al., 2016). However, feed scarcity is still a significant issue within the dairy sector (Njarui, et al., 2021). Within Kenya, extension services that seek to promote technology use have tended to move away from the traditional formal model where extension officers visit farms. Instead, informal farmer-to-farmer extension has become increasingly common where a few farmers who are trained by NGO’s are relied upon to educate their peers themselves (Kiptot & Franzel, 2015). Farmer-to-farmer information transmission was argued to be the main driver of forage diffusion in Kenya (Wambugu, et al., 2011).

3.3 Methods

3.4.1 Data Collection

This study uses village level survey data collected by the International Livestock Research Institute (ILRI) in Kenya and Ethiopia in 2015. Village level data allows for the wider contextual factors that impact forage adoption to be understood and does not focus solely on individual farm characteristics.

The villages included in the data collection were selected based on their location as forage production in both countries is concentrated in certain domains. In Kenya, counties were used to identify forage production domains. Counties are the first administrative unit in the country and typically account for around 500,000 to 2 million people, with the exception of Nairobi County which covers over 4 million (Kenyan Bureau of Statistics, 2019). In Ethiopia, forage production is far more limited meaning woredas, the third administrative units after zones and regional states, were used to identify forage production domains. There were 769 woredas registered in Ethiopia in 2008 (Yilmaz & Venugopal, 2008), with an average of 108,000 people per woreda (The World Bank, 2022).

The location selection in Kenya initially began with identifying general areas of the country where sufficient forage was grown. Five regions were chosen: Upper Rift, Western, Nyanza, Central and Coast. The counties within these regions were then ranked based on their dairy density, which is a good indicator of forage demand. Various datasets were used to determine dairy density and a final list of 12 counties were identified. These were Trans-Nzoia, Bungoma, Kakamega, Nandi, Uasin Gishu, Homa Bay, Nyamira, Kisii, Nyandarua, Murang'a, Kiambu and Kilifi.

In Ethiopia, four regions were selected based on their forage production. These were: Tigray, Amhara, Oromia, and Southern Nations, Nationalities and Peoples Region (SNNPR). Expert knowledge was then used to select 20 woredas within these regions that were most relevant for forage production. The 20 woredas contained 545 kebeles (peasant associations). In

Kenya, a single village was randomly selected from each selected sub-location as group discussions on a sub-location level would not have yielded reliable results. In Ethiopia on the other hand, kebeles were used as final selection unit and are also referred to as villages in this study, as according to local experts, kebele members would be able to provide responses regarding the whole kebele during group discussions. To allow for efficient comparisons between the different counties and woredas, an equal number of villages from each location were chosen from each. In total 360 villages were surveyed, 180 in each country. The locations of the villages surveyed are shown in Figure 3.2.

In the selected villages, a survey was carried out with focus groups of between 5 and 8 villagers. These villagers had to have knowledge of the entire village and of its forage and dairy production. They also had to represent a mix of farm sizes and be at least one third male and one third female.

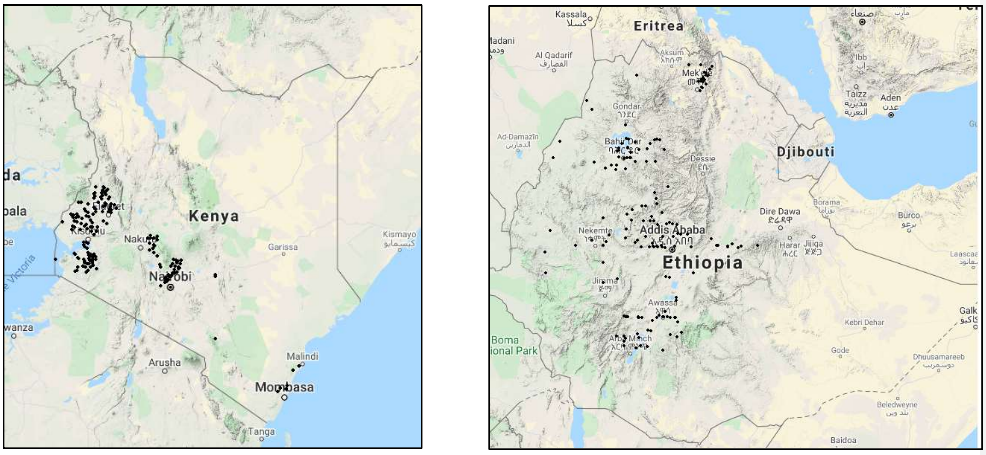

Figure 3.2: Locations of villages surveyed

3.4 .2 Dependent and Independent Variables

The variable 'forage intensity' was created from the survey data to represent adoption and form the dependent variable in the subsequent statistical analysis. Forage intensity is the amount of arable land per village that is dedicated to cultivated forages and was calculated by taking the total amount of arable land, dividing it by the amount of village land dedicated to cultivated fodders and multiplying by 100 to convert it in a percentage. Most static adoption models use binary independent variables that are categorised into 'adopters' or 'non-adopters'. However, these models may lead to biased results as the adoption process does not necessarily have a defined end point. The forage intensity variable falls between 0% and 100% allowing for different levels of adoption to be captured. As the AIS paradigm emphasises that adoption is a process, it was important to select a variable that was able to capture this.

Figure 3.3 shows the distribution of forage intensity for Kenya and Ethiopia. In both countries forage intensity is skewed to the left, with many values gathered around 0%.

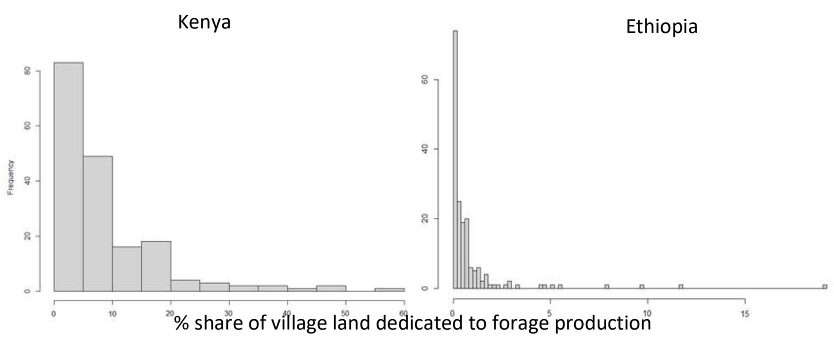

Figure 3.3: Histogram of forage intensity variable

9 independent variables related to village characteristics and village dairy production were selected to be included in the statistical analysis. These variables were chosen as they capture the differences in the dairy systems and can therefore help identify the wider contextual factors

that are important in the adoption of forages. The independent variables and what they measure are detailed in Table 3.1.

To provide insight into how market orientated smallholders are, the variables market integration, access to a milk collection centre and distance to town centre were selected. A greater amount of market orientation increases the likelihood that farmers within the village will have access to other actors in the AIS. This can result in increased information sharing and farmer knowledge of new innovations.

Market integration was expected to have a positive effect on forage adoption as it increases the likelihood that farmers are interacting with other actors in the AIS at the marketplace. Some buyers may offer training or provide inputs to farmers, which may increase their knowledge and use of forages.

Milk collection centres allow smallholders to sell and store their milk so that it can be sold on in bulk to formal buyers. They create important links between smallholders and buyers, including commercial buyers and processing plants (Vernooij, et al., 2010). Milk collection centres are often tied to dairy cooperatives, who usually provide training and inputs for their membership. It was therefore expected that the presence of a milk collection centre in a village would be positively associated with forage intensity.

Distance to the nearest town centre was expected to have a negative effect on forage adoption. Distance to the town centre is a proxy for market access as farmers in more rural locations are likely to be further from markets. Previous studies have found that the intensity of dairy systems differs based on access to milk markets (Didanna, et al., 2018), with higher access being linked to higher intensity and input use.

The variables dairy intensity, percentage of land tilled by tractors, access to informal finance and village savings were chosen to provide insight into villages and the informal institutions within them.

Dairy intensity is a measure of the proportion of dairy livestock in a village. A high proportion of dairy livestock will result in smallholders within the village requiring more dairy feed. This would result in more demand for forages and more forage cultivation. It was therefore anticipated that dairy intensity would have a positive effect on forage intensity.

Percentage of land tilled by tractors is an indicator of cash crop production which would reduce the space dedicated to forage production. Therefore, this variable is expected to have a negative effect on forage intensity.

Access to informal finance and village savings were expected to have a positive effect on forage intensity. They both rely heavily on socially enforced norms and rules and are often built on a basis of strong social capital (Mwangi & Ouma, 2012). Social capital is linked to high levels of information exchange, skill transfer, exchanging of livestock gifts and technology promotion (Ntume, et al., 2015). Having access to financial resources also increases the capacity of farmers to invest in their farm, potentially increasing investment in forage cultivation.

A key element of AIS are the bridging institutions that aim to provide smallholders with information and training and help to create links between smallholders and other actors within the innovation system. Due to the challenges of reaching rural populations, access to bridging organisations can differ based on location and often villages that are closer to urban areas benefit from a greater number and diverse range of actors (Ergano, et al., 2010). Access extension officers and the number of forage projects in the village were both used as indications of how effective bridging organisations in the AIS were.

Forage projects and extension officers seek to transmit new information and innovations from other actors within the AIS directly to smallholders. They also offer training and occasionally provide inputs directly to the farmers. It was expected that the number of projects and having access to extension officers would have a positive effect on forage intensity as farmers would have received more education and training on the benefits of forage cultivation.

Table 3.1: Independent Variables

Variable name	Explanation	Unit of measurement	Statistics			
			Kenya n=180		Ethiopia n=180	
			Mean	S.D	Mean	S.D
dairy_intensity	What proportion of total livestock are dairy livestock?	Percentage (%)	15.28	19.15	2.5	6.65
market_integration	What proportion of milk produced is sold?	Percentage (%)	63.7	23.4	32.03	33.84
no_projects	The number of projects that are active, or have been active, within the village.	Number of projects	0.43	0.74	1.24	0.69
distance_to_town	Distance to the nearest town	Km	7.56	12.6	17.04	13.41
perc_tractor	What proportion of land is tilled by tractors?	Percentage (%)	18.73	31.8	0.19	2.26
extension	How many out of the following types of extension operate in the village: Dairy, Crop and Fodder.	Integer.	0.66	1.15	2.43	1.16
			% of villages			
milk_coll_centre	Does the village have a milk collection centre in it?	Dummy: 1 = Yes, 0 = No	26		9	
village_savings	Does the village have savings' groups?	Dummy: 1 = Yes, 0 = No	5		10	
informal_finance	Are there informal finance options available within the village?	Dummy: 1 = Yes, 0 = No	70		66	

3.4.3 Empirical Specification

The statistical analysis uses a Tobit regression model to test which village characteristics affect the independent variable, forage intensity. As forage intensity is measured as a percentage between 0% and 100%, it cannot fall below 0% which means that all non-adopters will be censored and will accumulate at this point. With data that is censored it is appropriate to use a Tobit model as they are designed to estimate linear relationships between variables when there is either left or right censoring in the dependent variable. The structural equation of the Tobit model is shown below:

$$y^*_{i=}x'_i\beta + \varepsilon_i$$

Where y_i^* is the non-observed latent variable, represented by the dependent variable, fodder intensity. x is the vector of independent variables hypothesised to influence adoption. β represents the parameters associated with the independent variables. ε is the random disturbance term. y_i is the observed component of the dependent variable.

The observed values for y are defined by:

$$y_i = y^* \text{ if } y^* > \tau$$

$$y_i = \tau_y \text{ if } y^* \leq \tau$$

where the data is censored at τ, in this case at 0.

Separate Tobit regression models were estimated for Kenya and Ethiopia. As explained above, the differing characteristics and contexts of these innovation systems requires us to accommodate these in different models. Separate models provide insights into how the different institutional contexts may affect adoption and allow for comparisons between the innovations systems in the two countries.

Tobit models are dependent on the assumptions of homoscedasticity and normality. Therefore, before running the models the independent variables were checked for the existence of multicollinearity using the Variance Inflation Factor (VIF). A VIF value of over 5 can indicate the presence of multicollinearity. The highest VIF value for Ethiopia was 1.35 and for Kenya was 1.41, therefore multicollinearity is not a concern amongst the independent variables. Checks for homoscedasticity and normality where also carried out after the model was estimated and are discussed with the model results.

3.5 Results

3.5.1 Descriptive Statistics

The villages surveyed contained an average of 175 households for Kenya and 1156 for Ethiopia. Within these villages, over 90% of households in both countries participated in some form of farming activity. A minority of households in both countries had access to electricity, only 18% in Kenya and 10% in Ethiopia. In Kenya, 8.7% of crop land was used to grow forages which made up 34% of the livestock feed. In contrast, only 1.6% of crop land in Ethiopia was used to grow forages which made up only 7% of livestock feed. Correspondingly, the share of farming households planting forages was higher in Kenya with 53% of households growing at least one species of forage, compared to 19% in Ethiopia.

Table 3.2: Descriptive statistics

	Kenya n=180		Ethiopia n=180	
	Mean	S.E	Mean	S.E
No. Households[1]	175	17.16	1156	69.1
% of households that farm[1]	93	1.07	96	0.73
% of farming households with a female head [1]	20	1.05	15	0.8
% Households with electricity [1]	18	2.11	10	1.39
% of village land used for cultivated fodder [1]	8.7	0.74	1.6	0.37
% of hh planting forages [1]	53	2.36	19	1.63
% of livestock feed that comes from planted fodders [1]	34	1.62	7	0.63
Average yield of milk per local cow per day (litres) [1]	0.7	0.06	1.4	0.04
Average yield of milk per cross-bred cow per day (litres) [1]	5.36	0.22	3.76	0.2

Average number of months villages experiences a shortage of grazing land [1]	3.19	0.17	7.45	0.14
	% of villages			
% of villages with access to a crop extension officer[1]	23		89	
% of villages with access to a fodder extension officer[1]	26		89	
% of villages with access to a dairy extension officer[1]	21		84	
Note: [1] values based on village-level aggregates				

Across both countries a range of different forage species were adopted. Table 3.3 shows the number of households growing each type of forage in both Kenya and Ethiopia. Within Kenya, local Napier varieties were the most popular forage. There is a long history of growing Napier in Kenya, especially in the high-rainfall, high-density areas around Mt Kenya, to feed livestock, with farmers tending to rely on it as their main source of feed (Gachuiri, et al., 2017). Improved Napier varieties were the second most popular forage grown in Kenya. Within this study, Napier grass is separated into local and improved varieties due to considerable research efforts, including by CGIAR centres (CGIAR, 2022) being focused on these, and because of their wide-spread adoption in Kenya. Calliandra trees, a small tropical leguminous tree that can 'tolerate harsh climatic conditions…providing nutritious animal feed' (Makau, et al., 2020, p. 2) were the second most commonly adopted forage. In contrast, within Ethiopia, Sesbania was the most adopted forage type. It is an easily grown legume with a high nutrient content. This was then followed by local Napier varieties.

Table 3.3: Percentage of households planting each forage species

	Type of Forage	Kenya n=180	Ethiopia n=180
Grass	Pennisetum purpureum *(Napier Kaka 1)*	1.79	0
	Pennisetum purpureum *(Napier Kaka 2)*	1.07	0
	Pennisetum pedicellatum	0.33	1.99

	Chrysopogon zizanioides	0	0.16
	Avena sativa	1.67	0.89
	Sorghum	1.86	0
	Pennisetum purpureum *(Other improved varieties)*	3.53	0
	Setaria	0.22	0
	Maize	0.57	0
	Pennisetum purpureum *(Local varieties)*	35.06	5.32
Herbaceous Legumes	Desmodium	0.51	0.03
	Vetch	0.12	1.4
	Medicago sativa	0.04	1.43
	Trifolium	0	0.004
	Cajanus cajan	1.33	1.13
	Lablab purpureus	0	0.18
Trees	Cytisus proliferus	0	0.07
	Calliandra	2.43	0
	Leucaena leucocephala	1.22	1.05
	Sesbania	0.51	11.33

Villagers were also asked where they obtained the seeds or planting materials for their cultivated forages. Some forages, such as Napier, are often shared vegetatively, i.e. as splits, due to challenges of seed production and growing from seed. Table 3.4 shows the percentage of seeds and planting materials acquired from different sources. In Kenya, neighbours and private stockists/vets were the main sources, while both the Ministry of Agriculture and other farmers provided less than 8% of seeds and planting materials each. In contrast, in Ethiopia, the Ministry of Agriculture dominates the provision of seeds and planting materials, supplying around 86%. All other sources in Ethiopia hold much smaller shares and are mostly formal organisations such as NGO’s.

Table 3.4: Sources of seeds and planting materials

Kenya		Ethiopia	
Source	**% of seeds/planting materials**	**Source**	**% of seeds/planting materials**
Neighbours	46.9	MoA	86.6
Agro/vet/stockist	14.4	International NGO	7.7
MoA	8.8	ILRI	1.3
Other Farmers	8.5	National NGO	0.7
Others	21.4	Others	3.7

The types of forage project organisations that are active, or have previously been active, in the villages surveyed are shown in the charts in Figure 3.4. International NGOs are the main implementers of forage projects in Kenya. The most prevalent of these was Vi Agroforestry, a Swedish NGO that works in collaboration with farmer organisations to promote sustainable land management. It ran projects in 15 different villages included in this study. Farmer groups were the second largest provider of projects in Kenya. The chart for Ethiopia shows that the government runs 80% of projects on forage production in the country.

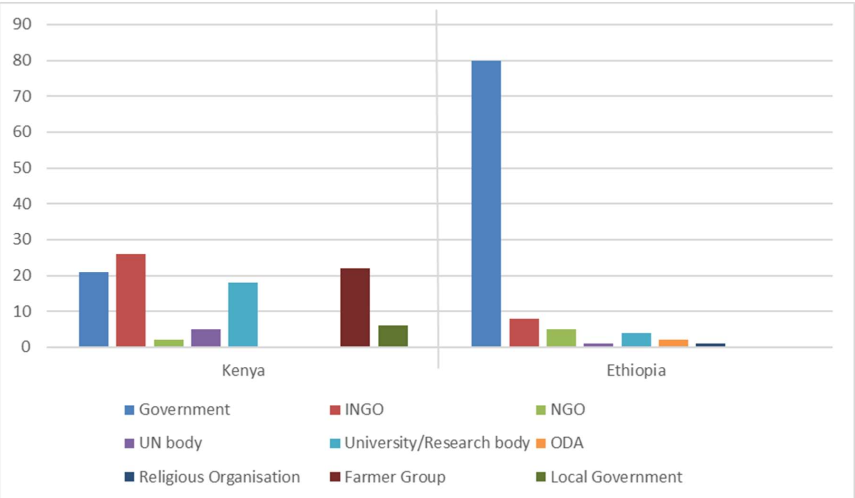

Figure 3.4: Percentage of projects run by each organisation type

The results of the Tobit regressions are shown in Tables 3.5 and 3.6. To ensure the models met the requirements of a Tobit regression in terms of normality, the residuals of both regressions were plotted out in density plots. These are in the appendix. Both plots are skewed left, but roughly follow a normal distribution and were therefore determined to meet the normality requirement. To test for heteroscedasticity, Breusch-Pagan tests were used. The results shows that heteroscedasticity was not a problem and therefore the data adequately meets the criteria for a Tobit regression. The McFadden Pseudo R2 for the Kenya Tobit was 0.26 and Ethiopia was 0.24. McFadden stated that a Pseudo R2 of above 0.2 indicates the model has a very good fit (McFadden, 1977)

In Kenya, dairy intensity and market integration were all positively and significantly associated with forage intensity while distance to the nearest town and the percentage of land tilled by tractors was negatively associated with forage intensity. In Ethiopia, market integration was positivity and significantly associated with forage intensity.

The marginal effects in Table 3.5 show that in Kenya an increase of 1% of milk sold to buyers, which represents market integration, was associated with an increase of forage intensity of 0.08%. For dairy intensity, an increase in the proportion of total livestock that are used for dairy production by 1% is associated with an increase in forage intensity of 0.08%. An increase in the distance to town by one-kilometre results in 0.1% lower forage intensity and an increase of 1% of the land tilled by tractors results in a 0.09% decrease in forage intensity.

The marginal effects in Table 3.6 show that in Ethiopia, a 1% increase in market integration is associated with a 0.02% increase in forage intensity.

Table 3.5: Tobit results for forage intensity in Kenya

Coefficient	Standard Error	Marginal Effect
dairy_intensity	0.03**	0.08**
market_integration	0.03**	0.08**
no_projects	0.87	0.79
milk_coll_centre	1.63	2.68
extension	0.59	0.28
village_savings	3.07	0.75
informal_finance	1.41	-0.57
distance_to_town	0.01*	-0.1*
perc_tractor	0.02***	-0.09***
Pseudo R2: 0.26 Left-censored observations: 14 Right-censored observations: 0 Uncensored observations: 166		

*Note: Significance Codes: . p<0.1, * p<0.05, ** p<0.01, *** p<0.001*

Table 3.6: Tobit results for forage intensity in Ethiopia

Coefficient	Standard Error	Marginal Effect
dairy_intensity	0.06	0.04
market_integration	0.01**	0.02**
no_projects	0.58	0.03
milk_coll_centre	1.50	-0.76
extension	0.35	0.11
village_savings	1.38	-0.35
informal_finance	0.90	-0.65
distance_to_town	0.03	-0.01
perc_tractor	0.17	-0.05
Pseudo R2: 0.24 Left-censored observations: 11 Right-censored observations: 0 Uncensored observations: 166		

*Note: Significance Codes: . p<0.1, * p<0.05, ** p<0.01, *** p<0.001*

3.6 Discussion

The data used in this study was gathered from dairy orientated regions of Kenya and Ethiopia, however some of the common themes that emerge from these results may be applicable to other dairy intensive regions in East Africa. Data from the survey shows that both countries are experiencing low milk yields and feed shortages which can be addressed through the increased use of planted forages. Low milk yields are linked to lower levels of smallholder nutrition and food insecurity, both of which are pressing issues across East Africa. Previous studies have found that incorporating forage into livestock diets is one of the most important variables influencing the milk yield of dairy livestock (Osele, et al., 2018) and that milk yields from cross-bred cows in Kenya and Ethiopia can go above 10 litres per day given the right climatic and environmental conditions (King, et al., 2006) (Tamiru & Amza, 2017). In the villages surveyed, average daily milk yields for cross-bred cows were far below this at around 5 litres in Kenya and 4 litres in Ethiopia. Shortages of fodder were experienced, on average, over 5 months a year in Kenya and nearly 7 months a year in Ethiopia. An increase in planted forages, especially those that are resistant to specific climatic conditions can help overcome these shortages. Alongside this, previous studies have noted that adoption of forages in both countries is generally low (Gebremedin, et al., 2003) (Njarui, et al., 2017). There is therefore strong evidence to support the need for effective forage adoption policies that can contribute to nutritional and food security. This discussion section therefore looks at the different elements of the forage innovation system, the effects they have on forage adoption and how policies can be designed to effectively promote the uptake of forages in both countries.

3.6.1 Extension Services

Extension services are provided by public or private bodies and traditionally involve an extension officer visiting farms to provide education and training. They are an important bridging organisation in AIS, offering a vital line of communication between smallholders and other actors and, depending on their design, can support the co-development of innovations to meet smallholder needs. Effective extension systems are therefore an important part of AIS as they can link together actors and facilitate information sharing. In recent years there has been a shift towards farmer-to-farmer extension where a few farmers are trained and are then expected to educate and train their peers themselves (Kiptot & Franzel, 2015). This approach to extension is in-line with the idea that for AIS to be successful, farmers and their needs must be at the centre. However, this study does not capture the effects of these newer extension approaches, instead focusing on access to traditional extension officers.

The descriptive statistics in Table 3.2 show that over 80% of the Ethiopian villages surveyed had access to fodder, dairy and crop extension officers. This supports previous claims that Ethiopia has one of the most extensive agricultural extension systems in the world (Berhane, et al., 2018) with extension workers being present in 'every rural community' (Berhanu & Poulton, 2014, p. 207). Despite these impressive credentials, forage adoption in Ethiopia is low indicating that the extension system may not be working effectively. The regression analysis also showed that in Ethiopia access to extension officers did not have a significant impact on forage intensity. However due to the high prevalence of extension officers and therefore little variation, not much can be inferred from this result. In a review of the current literature regarding the Ethiopian extension system, Albore (2018) argues that most of the problems in the extension system are institutional. Unclear approaches to development, a lack of budget and talent and poor market linkages, amongst many other things, have prevented the system from operating effectively (ibid.). Meanwhile, strong government involvement within the Ethiopian agricultural sector has crowded out other actors (Spielman, et al., 2010) increasing the reliance of farmers in rural locations on the public extension system. Evidence of strong government involvement can be seen in the data as the Ministry of Agriculture provided over 80% of forage seeds and planting materials and ran over 80% of the forage projects in the villages studied. This combination of inadequate extension services and few alternative information sources may have contributed to the overall low levels of forage adoption in Ethiopia.

Access to extension officers was also not a determinant of forage intensity in Kenya. However, lower numbers of extension officers and preferences for alternative extension methods may explain this. Volunteer Farmer Trainers (VFTs) are a popular form of forage extension used in Kenya (Kiptot & Franzel, 2019). Specific farmers, who are the VFTs, are trained by NGO's and provided with seeds/planting materials under the assumption they will then educate their peers and pass on the seeds/planting materials (ibid.). The data in Table 3.4 shows that over half the seeds and planting material sources for the forages in Kenya come from other farmers or neighbours, suggesting that this extension approach could be successful as information and materials are already being exchanged between peers and that strong informal institutions exist between farmers. The reliance of farmers on their peers for information regarding forages has also been acknowledged by Wambugu et al (2011) who stated that farmer-to-farmer information transmission is the main driving force behind forage diffusion in Kenya.

3.6.2 Market orientation

The variables market integration and distance to town were used as indicators of how market orientated smallholders in the village were. Distance to town was used as a proxy for market access, therefore the negative relationship between distance to town and forage intensity indicated that villages that were closer to towns and had better market access were more likely to dedicate a higher proportion of land to forage production. The positive association between market integration and forage intensity shows that in villages where a higher proportion of milk was sold, there tended to be more forage adoption.

The milk market in Kenya is governed by both formal and informal institutions and can bring together various actors from different parts of AIS to exchange both knowledge and milk. They offer an opportunity for informal networks to form which are crucial to the successful operation of AIS. The informal milk market in Kenya accounts for around 80% of milk being marketed (Blackmore, et al., 2022). These markets operate on a trust-based system in relation to milk quality and safety, with buyers trusting that the milk is of a certain standard and social enforcement mechanisms preventing sellers from marketing low quality milk. Information shared at these markets regarding innovations is likely to be more trusted as it comes from individuals who may be similar to each other in terms of risk perceptions, needs and dairy orientation, and because strong informal institutions already exist which reinforce the trustworthiness of other market participants. There is also a formal milk market in Kenya where buyers such as cooperatives and private companies purchase milk from smallholders if it passes formal safety checks. These types of buyers may offer smallholders training and access to inputs which may result in higher forage use. Being more market orientated also indicates a stronger focus on dairy production as a business and key livelihood strategy, which may result in farmers being more willing to invest in forage technologies in improve their dairy production. All these factors are likely to have contributed to the effects of distance to the nearest town and market integration on forage intensity.

In Ethiopia, the only statistically significant relationship identified in the Tobit regression was a positive association between market integration and forage intensity. This result is particularly interesting as previously discussed, the Ethiopian government dominates many of the bridging institutions and information channels through which smallholders receive farming information. However, milk markets with formal buyers and informal buyers offer smallholders the ability to interact with other AIS actors that are not government affiliated. Formal buyers in Ethiopia, such as cooperatives or private companies have been found to offer advice, training and credit to directly increase the capabilities of farmers (Vandercasteelen, et al., 2021). In an innovation system that is dominated by public organisations, milk markets and formal buyers may be an important alternative channel for information and different approaches to educating and training smallholders on forage cultivation. It is also likely that, similar to Kenya, farmers who are selling more of their milk are more likely to invest in their milk production as a business, which may include dedicating more resources to forage production.

3.6.3 Village Characteristics

Certain village characteristics will impact whether it is viable or beneficial for farmers to plant forages and effect how easy it is for smallholders to access information regarding forages and other innovations.

The percentage of land tilled by tractors was negatively and significantly associated to forage intensity in Kenya. Tractors can make the large-scale production of cash crops easier and more profitable for farmers, meaning they are more likely to choose to use their land for growing cash crops as opposed to forages. Dairy intensity, which is a measure of the proportion of total livestock that are used for dairy production, had a positive effect on forage intensity in Kenya. Feeding forages to dairy livestock can increase their milk yield (Osele, et al., 2018), meaning in villages with a high level of dairy intensity there will be more demand for forages. This may also increase the market price of forages, encouraging smallholders to not only grow forages to feed their own livestock and but also to sell to other smallholders.

Both dairy intensity and proportion of land tilled by tractors provide an indication of how focused a village is on dairy production versus other agricultural outputs. The results therefore show that in villages were dairy is a more important livelihood strategy, forage intensity is likely to be higher. Whilst this relationship may exist for many reasons, including the increases in demand for forage and lower opportunity cost for using forage land, as discussed above, the role of information and knowledge sharing in these villages is a key area for future research. Higher numbers of dairy farmers may result in increased information sharing on dairy, with new knowledge and experience of various innovations being passed between farmers who trust one another. This may then lead to increased forage use.

4 Conclusion and policy implications

This study has explored the forage innovation systems of both Kenya and Ethiopia. It has looked at how the adoption of forages can offer a cost-effective way to increase livestock productivity, which can have positive effects on food security. These factors are priorities for both the Kenyan and Ethiopian governments (Ramos, et al., 2020) (Tura, 2019) and effective policies can help them be achieved. Several observations can be made from the results of this study which can help direct future research and policy. These are discussed below.

The data analysis in this study offers support for the idea that farmer-to-farmer information transmission is important in Kenya and that it may be an effective channel for forage promotion. The high proportion of forage materials that were exchanged between peers indicate that strong informal institutions already exist. Meanwhile, the positive effect that the market orientation variables and how the dairy production variables had on forage intensity suggests that markets and villages with a high proportion of dairy farmers offer an environment for farmers to share trusted information with one another. In these settings, farmers can exchange advice and knowledge and learn more about the benefits of innovations (Ntume, et al., 2015). Whilst it is likely that other factors also influence these relationships, farmer-to-farmer information sharing is a cost-effective way to promote forages, and also puts farmers at the centre of the AIS. This can help the system become more demand driven and ensure it meets smallholder needs. It is therefore a key area for future research to determine the magnitude of the effect of knowledge exchange on forage adoption in these settings.

The evidence from Ethiopia raises questions about the effectiveness of the government's approach to forage promotion. Despite strong state involvement in forage projects, extension services and the provision of seeds and planting materials, the Ethiopian villages have lower levels of forage adoption intensity and milk yields when compared to their Kenyan counterparts. Even though this approach provided farmers with access to bridging institutions that link smallholders to other actors in the AIS, its top-down nature in which the government provides farmers with materials and information in a linear manner fails to facilitate the co-design of innovations, resulting in smallholder demands and needs being ignored. The positive effect of market integration on forage intensity suggests that there is an important relationship between milk buyers and forage adoption which needs to be explored further. As discussed previously, milk buyers both formal and informal may be important sources of information that are not government controlled. Therefore, focusing on creating a more pluralistic AIS with a greater range of actors, and stronger bridging institutions that seek connect these actors together, may help increase the uptake of forages in Ethiopia.

It is therefore concluded that future policies designed to address food and nutrition insecurity of smallholders would benefit from focusing on the promotion of forage use. Whilst further research needs to be carried out to understand the extent of information sharing in certain environments and the role this has on forage adoption, some general points for future policy makers can be made. AIS should be pluralistic to ensure smallholders have access to various forms of information. In these pluralistic structures, strong bridging institutions need to exist which link smallholders to other actors and which also facilitate discussions and co-learning as opposed to linear, one-way information transfers. Farmers should also be encouraged to share information and knowledge with their peers, this can be done through the creation of more farmer-to-farmer extension projects, or through farmer groups such as cooperatives. Whilst these results directly apply to Kenya and Ethiopia, these factors are important in facilitating effective information transfer and innovation design in AIS and therefore can be applied to all high dairy potential regions of East Africa and the wider agricultural sector in SSA.

Chapter Four: What can social network analysis teach us about farmer-to-farmer extension services? Evidence from dairy farmers in western Kenya.

4.1 Summary

Chapter 3 of this thesis argued that in Kenya, informal interactions between farmers were resulting in increased forage adoption. This was due to increased information sharing between dairy farmers at market hubs and the exchanging of planting materials between peers. Information that is shared between peers is often viewed as more trustworthy, which is particularly relevant in the African context as many governments and organisations have sought to capitalise on this ~~phenonium~~ phenomenon to make their agricultural extension strategies more efficient. Extension services have traditionally involved agents going directly to farmers and training them, an approach which has had mixed success (Davis, 2008). More recently, across SSA there has been a move towards farmer-to-farmer (F2F) extension in which 'lead farmers' are trained and then expected to educate those in their networks through a process of social learning.

This chapter focuses on how F2F extension strategies can be made more effective by using social network analysis to analyse the network structures, power dynamics and influential individuals within informal farmer networks. It analyses data collected in western Kenya in 2022 and provides evidence of the uniqueness of farmer network structures. It argues that for F2F extension to be made more effective, policy makers should focus on mapping out social networks to identify individuals who hold specific network positions.

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4.2 Introduction

Social networks are an important element in Agricultural Innovation Systems (AIS) (Ogada, et al., 2014) (Villarroel-Molina, et al., 2019), yet the research that focuses on their structure and the power dynamics within them is limited. Most of the existing literature on social networks in AIS does not use sociometric data and relies on proxy indicators such as number of friends or group membership to represent networks. This fails to adequately capture the intra-community dynamics, information flows and power relations that exist within networks and that are important when trying to ensure interventions reach those who need them (Hoang, et al., 2006). The limited studies that have used sociometric data and social network analysis (SNA) have highlighted the benefits that understanding network structure can have on inclusivity, the speed of information diffusion and the potential reach of information (Beaman & Dillon, 2018) (Nöldeke, et al., 2019).

In recent years African countries have increasingly adopted farmer-to-farmer (F2F) extension models in which smallholders play an influential and active role in spreading knowledge of innovations. This extension style relies heavily on farmer relationships and networks for its success as farmers are expected to learn from their peers. Increasing our understanding of farmer networks can therefore provide insight into how knowledge diffuses, which can be used to inform F2F extension approaches. Focusing on smallholder dairy networks in Kenya, this study seeks to contribute to the emerging body of literature on the network structures of farmers in sub-Saharan Africa (SSA) and how they can be used to make F2F extension more effective.

Initially, this study provides background on extension systems in SSA and the importance of social networks. Survey data from smallholder dairy farmers, collected from western Kenya in February 2022, is then analysed using social network analysis (SNA) to provide an insight into network structures, power dynamics and information flows. Finally, the results of the data analysis and how they can be used to inform future policy are discussed.

4.2.1 Agricultural extension services in sub-Saharan Africa

AIS rely on access to information that provides end users with knowledge on the benefits and use of a certain technology. In the African context, this has traditionally occurred through a linear extension system in which extension agents go directly out to smallholder farmers and train them. This approach, however, has had mixed success and has received criticism for its cost-effectiveness (Davis, 2008). As a result, a new paradigm of agricultural extension and education has emerged over the last decade that focuses on 'bottom-up' and collaborative approaches and in which smallholders are ‘catalysts and facilitators helping their own communities’ (Kiptot & Franzel, 2015, p. 504). These models rely on F2F information transmission, as farmers are more likely to trust information that comes from their peers. Informal networks are crucial in this process as trusted information often flows freely between members.

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The limited success of traditional extension models has been attributed to multiple causes. Eicher (2002) argues that the complex institutional arrangements that smallholders exist within is one of the biggest challenges facing the African Ministries of Agriculture. Smallholders have their own diverse cultures and may have high levels of distrust in authority which can prevent any knowledge or information shared by extension officers being acted upon. Reaching a significant proportion of the population can be also challenging and expensive, with Tchouama and Steele (1997) finding that in their study on extension in Cameroon, only 30% of respondents had contact with an extension agent over a five-year period. Those that did have contact struggled to translate what they were told into their day-to-day practice. A lack of communication skills amongst extension officers has also been found to reduce their effectiveness (Davis, 2008).

The F2F extension model can overcome many of these barriers and can offer a cost-effective way to reach large numbers of farmers. The F2F model focuses on a lead farmer who is trained and educated on certain innovations and helped to set up a demonstration plot

(CGIAR, 2020). This means only a few farmers are directly trained by official extension agents, significantly reducing costs. Information regarding the innovation is expected to be passed on from the trained farmer through their informal networks, and as farmers are more likely to trust information from their peers, they may regard this information with more credibility and overcome the issues of distrust in traditional extension agents.

F2F extension has been applied across SSA, with different models using slightly different approaches. In Tanzania, the government has trialled a model in which lead farmers, extension officers and NGO workers hold training sessions and create demonstration plots together. The lead farmer is required to invite at least five additional farmers to this plot to learn (Nakano, et al., 2018). In Malawi, a single farmer is chosen from each village and is expected to train, advise and monitor other farmers in the village (Fisher, et al., 2018). In western Kenya, the focus region of this study, two main F2F extension projects exist: Volunteer Farmer Trainers (VFT's) and Village Based Advisors (VBA's). As with the other F2F projects across SSA, they involve training several lead farmers and helping them create demonstration plots so they can exhibit new agricultural methods and educate their peers (CGIAR, 2020). The lead farmers are also encouraged to earn income from selling inputs and services to their peers which promotes entrepreneurship and makes the project more sustainable in the long run. Evidence suggests that these projects have been successful in mobilising and training farmers, distributing materials and in enhancing technology adoption and productivity (Lukuyu, et al., 2012) (Nakano, et al., 2018).

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F2F extension can also occur through farmer groups, such as agricultural cooperatives. These farmer groups offer a natural setting for farmers to discuss new information and agricultural innovations. In Kenya, cooperatives have utilised this opportunity with one initiative, led by the Kenyan Market-led Dairy Programme (KMDP), focusing on training a lead farmer who is well respected within the cooperative and supporting him to demonstrate new practices to others within cooperative network (Kilelu, et al., 2018).

4.2.2 Social networks in F2F extension

F2F extension models are founded in social learning theory in which actors observe the actions of their neighbours and peers and then alter their own expectations and understanding based on these observations. As more members of a social group are exposed to a technology, those within the group learn more about its characteristics, which may initially have been hidden (Fafchamps, et al., 2022), and eventually a new shared perspective of the innovation will be created. This perspective frames the innovation in a manner than is understandable to the group and meets their needs. However, how effectively information and technology use spread through a group and therefore how effectively social learning occurs depends on the group network structure (Lamberson, 2009) and on who in the group people tend to copy (Barkoczi & Galesic, 2016).

Some social networks will have high levels of interconnection which often indicates the presence of bonding social capital. Bonding social capital is used to describe the benefits and positive outcomes that individuals in a homogenous network group receive as a result of network membership. In bonded networks, due to the high density of relationships, there are many different pathways that information regarding innovations can pass through to reach the entire network. Information has the potential to therefore spread quickly and easily between members. However, bonded networks can also be inward looking and distrustful, which reduces the extent to which new information enters the network (Pillai, et al., 2015).It also increases the likelihood of technology lock-in, where members are not open to new technologies and stick to what they, and the rest of their network, currently know (King, et al., 2019).

Commented [XC9]: Does bonding capital refer to network membership, or group membership (Marks and Stys, 2019; that andrew sent via email)? Or are the uses transferable?

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Other networks will be less densely connected but may have high levels of bridging social capital. Bridging social capital describes the benefits that occur from relationships between heterogenous actors within a network. In the context of this research, these networks may span farmers from different geographical locations or different social-economic backgrounds.

Often in networks with high levels of bridging capital there will be fewer potential pathways for information to travel via if it is to reach the entire network, meaning knowledge of an innovation may be slow to spread. In these networks, there are often individuals who hold important 'bridging' positions as they lie on a pathway that bridges two parts of the network together (Riemer, et al., 2015). Generally the ties in these networks tend to be weaker than those in bonded networks, however Granovetter argues in his work the "strength of weak ties" (1973) that such relationships may have many benefits as these weak ties can increase access to information that may not be easily obtained through an individual's own clique.

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Previous studies have also shown that the network position of the lead farmer will also affect how information spreads. Individuals within a network that hold bridging positions link together different groups within a network and will therefore be able to transfer information between these groups, potentially extending the reach of the information, a finding confirmed by Nöldeke et al (2019). Baeman and Dillion (2018) however, found that targeting individuals who occupy bridging positions to be the initial adopters of technology meant that farmers who have the least connections to other farmers tended not to receive any information on the innovation. They found that targeting farmers who had the most connections to other farmers to be the initial adopters was therefore a more inclusive strategy. It has also been shown that targeting farmers with the most connections can also increase the speed that information diffuses at (Nöldeke, et al., 2019).

4.3 Research Questions

This study seeks to identify ways in which F2F extension strategies can be made more effective through increasing our understanding of existing farmer networks. To do this, two different types of smallholder dairy farmer networks were selected: cooperative networks and non-cooperative networks. This allowed for comparison between the network structures of farmers who participate within dairy cooperatives and are therefore more likely to be integrated into the dairy value chain and have access to training and innovations, and between those who are still very much subsistence farmers or focused on selling small amounts of milk at local markets. Using data from these networks, this study will answer the following research questions:

Main research question

How can F2F extension strategies be designed to use existing farmer networks to maximise their reach and effectiveness?

Sub-research questions

What are the differences in the network structures of farmers in cooperatives versus those not in cooperatives?

What are the socio-economic characteristics of individuals who are important in information transmission?

How does technology adoption differ between the networks?

4.4 Materials and methods

4.4.1 Study Site

Data collection took place in western region of Kenya in 2022. The region is made up of 11 counties that border the Kenyan side of Lake Victoria and is one of the most populated rural areas in the world with over 500 persons per sq km (Waswa, et al., 2013). The region is dominated by smallholder agriculture with farmers growing crops such as maize, sugarcane, beans and millet. Smallholder dairying is also an important livelihood strategy of those within western Kenya yet despite good climatic conditions, dairy productivity is low leaving the area in a milk deficit. Low levels of technology and input use are a key reason for this low productivity. The high, yet unrealised, dairy potential of the region has resulted in it being the focus of many dairy development projects, including both VFT and VBA. The VFT projects were initially set up by the Kenya Forestry Research Institute (KEFRI), Kenya Agricultural

Research Institute (KARI) and the World Agroforestry Centre (ICRAF) (Lukuyu, et al., 2012) and VBA projects have been led by Farm Input Promotions Africa (FIPs) (FIPS-Africa, 2022).

Four specific locations for data collection were identified with the help of the International Livestock Research Institute (ILRI), an international research centre that runs and supports numerous projects in western Kenya. Two locations that had well-established dairy cooperatives were chosen and two locations without cooperatives, where dairy productivity was low were chosen. Based on ILRI's previous work and knowledge of the area, two cooperative locations, Oyugis and Rongo, were selected as the cooperatives in these locations have a good-sized membership of around 400 active members. The locations without dairy cooperatives were selected using existing VBA dairy projects as this ensured that dairy was an important livelihood strategy in the area and that F2F extension was an important agricultural development strategy. Based on previous collaborations with the VBA's, ILRI were able to provide expert opinion on which locations would be appropriate for this study and the counties of Vighia and Siaya were selected. A description of each study site is given below, and their locations are shown by the red points in Figure 4.1.

Figure 4.1: Locations of data collection

Rongo dairy cooperative was established in 1988, making it one of the oldest in the region (International Livestock Research Institute, 2021). The cooperative has a membership of over 1,300 but with around 400 active members who contribute regularly. These members contribute around 4 litres of milk each daily to the cooperative, but it is operating far below capacity and is therefore actively seeking to increase membership. The cooperative has a large milk cooler to ensure milk that is collected can be stored effectively and has the facilities to produce yoghurt and other value-added goods. They also offer training and access to artificial insemination (A.I), for which there has been large investments across the entire country. Migori county, where the cooperative is located, is in a milk deficit, having to import milk from neighbouring countries to feed its population (Odhiambo, et al., 2019).

Kasbondo dairy cooperative is in the town of Oyugis in Homa Bay county. It was established in 2014 (International Livestock Research Institute, 2021) and has an active membership of around 400. Total membership is above 1000. The cooperative is mostly focused on collecting milk and value addition. It sells its milk products at the local market. Both the cooperative and wider county are part of A.I and breeding initiatives to try and increase the number of improved cows and therefore productivity. In recent years, the Accelerated Value Chain Development, a development initiative lead by several organisations gave the cooperative bulk milk chilling and pasteurizing plants that can process up to 10,000 litres of milk. This provides the cooperative with capacity to expand its membership and value-added production.

Vihiga county is in persistent milk deficit and has low commercialisation of smallholders. Across the entire country, only 1,500 litres of milk a day is produced but the county government aspires to increase this to over 5,000 (Ombima, 2021). There are currently no facilitates for milk processing in the county, which is important if farmers are to increase their production and find additional buyers. There are four dairy cooperatives across the county, they do not service the towns that were the focus of this study and they have struggled to create any substantial benefits due to a lack of funding and resources and poor management. VBAs operate in Vihiga to try and improve milk productivity and link smallholders to vets and input suppliers. They are an important source of dairy information and training in the locations we collected data. Vihiga county has an extremely high population density of around 886 people per square km, resulting in average farm size being relatively small at around 0.4 ha (UNEP, 2021).

Siaya county is also in milk deficit, with the vast majority of livestock being local breeds which are inefficient. Similar to Vihiga, Siaya has a few dairy cooperatives although none were operating in the areas used for data collection. These cooperatives have been struggling with volumes so low they are not breaking even and are considering closing. The Siaya county government views these cooperatives as an opportunity for smallholder commercialisation and aims to develop them. Various forms of F2F extension funded by different NGO's and organisations operate in Siaya and are often the only form of extension farmers have access to.

4.4.2 Data Collection

An initial sample of 10 participants was selected from the membership lists of the two cooperatives and from lists provided by the VBA lead farmer naming the farmers covered by their services. Individuals who had expert knowledge of dairy farming in the locations were asked to help select 10 participants from the lists who were representative of the wider dairy farming population in terms of gender, age and farm size. These initial participants where then asked to complete a survey, which included a range of open and closed questions related to their dairy production, technology use and information sources. In order to create the social networks, the survey also included a name generator question which asked the participant to name up to four people they talk to about dairy farming. A method of snowball sampling was then used in which those named by the participants in the name generator question were surveyed. This continued until the allocated time at the location ended, or until no new names were being generated. The individuals named through the name generator questions did not have to be present on the initial VBA or cooperative lists.

Snowball sampling is a popular method in SNA (see: (Fehr, et al., 2016) (Illenberger, et al., 2011) (Kowald & Axhausen, 2012) (Markantonatou, et al., 2015)) as it allows the researcher to collect relational data that can be particularly effective when dealing with hidden populations and poorly defined network boundaries (Hughes & Mutyala, 2014). However, the relational data should be homogenous with all links between the actors representing the same thing (Jensen & Neville, 2001). For this study there are no network boundaries and the data being collected is relational with each connection representing an information channel, making snowball sampling an appropriate technique.

There are some inherent biases with snowball sampling that needed to be controlled for in the design of data collection. Selection bias can occur as the initial participants will directly affect the composition of the next wave of participants, but also those later in the chain as they can be linked back to the initial sample. To help address this, the initial sample of participants were selected to ensure they covered a range of ages, farm sizes and both genders. This has regularly been cited as the best way to overcome snowball sampling selection bias (Etikan, et al., 2016) (Morgan, 2008) (Penrod, et al., 2003) (Waters, 2015). There is also a risk of homophily in which individuals are more likely to list those who are similar in certain characteristics resulting in a homogenous network. Again, ensuring the initial sample is representative of the wider population can help reduce this bias (Kowald & Axhausen, 2012).

The final form of bias comes from using the chain method itself, as the probability of being named by a participant increases with the number of personal connections that person has. For this research, identifying the most well-connected individuals in a network is important as they are likely to be influential in information transmission. However, to ensure these individuals were captured, but that the networks were not biased towards them, participants were asked to list four separate individuals in the name generator questions, although this could be less if they were unable to name four. Allowing for several names to be given during the name generator question reduces this type of bias (Kowald & Axhausen, 2012).

4.4.3 Social Network Analysis

SNA allows information flows and networks structures between farmers to be mapped out and analysed. To date, very few studies have used SNA to map out informal farmer networks and therefore our knowledge of them is limited. Those that have used SNA have highlighted the importance of network structure and network position in technology adoption, proving that SNA can be a useful tool to increase the effectiveness of F2F extension. This study therefore uses SNA to analyse data collected on dairy farmer networks in western Kenya.

SNA focuses on social relationships which are characterised as nodes (the actors in the network) and edges (the relationship between the actors). Network maps, known as sociograms, are often created and specific SNA metrics and statistics are applied to them. The different elements of SNA that are used in this study are detailed below.

Sociograms*:* Sociograms are a graphical representation of social links and are a core part of SNA. They allow social networks to be displayed visually which can help with attaining a realistic understanding of network patterns and interactions. Sociograms are often created from adjacency matrices which indicate whether two nodes are adjacent or not. Using the software R and the R package visNetwork, the adjacency matrices created for this study were turned into sociograms that provide a visual tool to understand the network structures.

Transitivity: Transitivity is also known as the clustering coefficient and is a measure of the tendency of nodes within a network to cluster together. A high transitivity means that within the network there are groups of nodes that are more densely interconnected. Information is likely to pass easily within these densely connected clusters, but less easily between them.

Diameter: The diameter of a network is the length of the longest path between two nodes therefore indicating how distant the two most distant nodes are. The diameter shows how compact a network is, with a high diameter indicating nodes are very distant and little compactness. A high diameter, however, does not mean the network does not have more compact and densely connected areas. A lower diameter indicates that the distance between nodes is shorter and therefore the graph is more compact and that all nodes are in proximity.

Centralisation: Centralisation measures the extent to which the nodes within a network are gathered around a single node or group of nodes. High centralisation in a network indicates that one or a few nodes are at the centre of the network.

Edge Density: Edge density is calculated by dividing the actual number of edges by the maximum possible number of edges. It shows how well interconnected those within the network are. A higher edge density indicates more connections between actors meaning there are a greater number of pathways for information to flow through.

Betweenness Centrality: Betweenness centrality is the measure of how many times a node lies 'between' others in the network. A node that is on the pathway of many other nodes would have a high betweenness centrality as information has to pass through it to reach other parts of the network. Nodes with a high betweenness centrality can therefore be important in ensuring information is passed through the entire network.

Degree Centrality: This is the number of links incident on a node. A high degree centrality indicates that the node is well-connected and therefore influential within the network.

4.4.5 Regression model

This study also uses two OLS regressions to identify what characteristics are associated with certain influential positions within a network. These positions are measured using betweenness centrality and degree centrality. The model was estimated using the following formula:

$$NP = \beta_0 + \beta_1 SE + \beta_2 GM + \beta_4 T + \varepsilon$$

In which NP represents the network position of interest i.e betweenness centrality or degree centrality. SE is a vector of socio-economic variables including age and gender, GM is a vector of membership to various groups including cooperatives and T is a vector of access to training and extension services. ε is the random disturbance term.

To ensure the variables selected were measuring the dependent variables, fitting statistics were calculated. The adjusted r^2 for the betweenness centrality regression was 0.10 and for degree centrality regression was 0.24. This shows the independent variables in the model explain 10% and 24% of the variation in the dependent variables, respectively. r^2 values of 0.10 are generally acceptable in social science as long as it is confirmed that some of the variables in the model have a significant effect on the dependent variable (Ozili, 2022). The F-Statistic for the betweenness centrality model was 2.7 and the p-value < 0.001. For degree centrality it was 5.7 and the p-value < 0.001. This shows that the independent variables both models are predicting the dependent variables.

4.4.5 Descriptive Statistics

For ease of understanding, the networks from Rongo and Kasbondo dairy cooperatives will be referred to as Cooperative 1 and Cooperative 2 respectively. The non-cooperative networks in Siaya and Vihiga will be referred to as VBA 1 and VBA 2 respectively.

Table 4.1 shows the descriptive statistics for each network. The average age across all networks ranged between 49 and 55. Farmers in VBA 1 had the lowest number of farming years, averaging 12 years per farmer. VBA 1 also had the lowest average amount of milk produced per week, with VBA 2 having the second lowest. Cooperative 1 and Cooperative 2 produced the most milk at 55.5 litres and 38.34 litres per week. Farmers in Cooperative 1 and Cooperative 2 also tended to have more cows on average and were more dairy intensive when compared to VBA 1 and VBA 2. Roughly half of each network were women, apart from Cooperative 1 were women made up just under 40%. The farmers in the cooperative networks tended to talk to farmers who lived further away about dairy farming when compared to the VBA networks.

Table 4.1: Descriptive statistics of the dairy production and socio-economic makeup of each network

	Cooperative 1 (Rongo) N = 67		Cooperative 2 (Kasbondo) N = 57		VBA1 (Siaya) N = 69		VBA2 (Vihiga) N = 62	
	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E
Average age	55.3	1.44	54.7	2.13	49.4	1.69	54.8	1.73
Average number of farming years	14.9	1.06	18.9	1.67	12.4	1.13	19.2	1.45
Average dairy intensity (%)*	23.4	2.45	25.9	2.73	13.7	2.06	23	2.53
Average number of cows	2.4	0.3	1.7	0.12	1.5	0.09	1.3	0.08
Average amount of milk produced per week (litres)	40	3.87	38.3	3.49	16.3	1.41	24.5	2.6
Average distance to market (km)	4.5	1.40	5.5	0.31	6.5	0.65	4.2	0.51
Average time in mins to walk to network connections	91.4	20.27	88	43.8	34.3	1.41	38	4.309
% of woman	39		50		48		56	
Social Capital **	4.6		4.7		4.1		4.5	

*Percentage of income that comes from dairy farming
**Calculated using a 1-5 Likert scale question regarding how positive of a relationship the individual had with others in their village

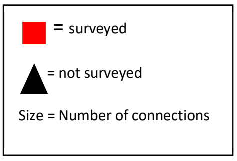
4.5 Results

The survey gathered data on the adoption of three different dairy technologies; livestock forages, A.I and vaccines. These were coded as dummy variables, with 1 representing the use of the technology and 0 representing non-use. Table 2 shows the proportion of each network that have adopted each technology. One-way ANOVAs were used to determine if there were any statistically significant differences in technology use between the networks. The ANOVA results showed statistically significant differences between all three technologies ($p<0.001$). As ANOVA's do not provide information about which groups are statistically different from one another, post-hoc tests can be used to carry out pairwise comparison and determine which groups are statistically different. Tukeys honestly significant difference (HSD) test is a commonly used post-hoc test that calculates the difference between two means using the studentized range distribution (Abdi & Williams, 2010). Tukey HSD tests were therefore used to carry out pairwise comparisons and identify which networks were statistically different in terms of technology adoption. The post-hoc Tukey HSD test showed that VBA 1 had statistically significant lower levels of forage use compared to the other networks. It also had lower vaccine use than Cooperative 2 and VBA 2 and lower A.I use when compared to both cooperative networks. VBA 2 also had statistically significantly lower A.I use than both cooperative networks.

Table 4.2: Technology Use in the Networks

	Cooperative 1		Cooperative 2	VBA1	VBA2
		% of network members that use each technology			
Forages	80		90	40	90
Vaccines	70		60	50	90
A.I	60		50	10	20

The sociograms of each network were created using the name generator questions in the survey. They are shown in Figures 4.2a, 4.2b, 4.2c and 4.2d. The squares in the sociograms represent farmers who were surveyed during the data collection. The triangles represent farmers who were named as a connection but were not surveyed due to distance, time or being unable to locate them. The size of the nodes represents how many direct connections they have, which is their degree centrality, and the links between the nodes represent the transfer of information. The network statistics for each network are shown in Table 4.3.



Cooperative 2

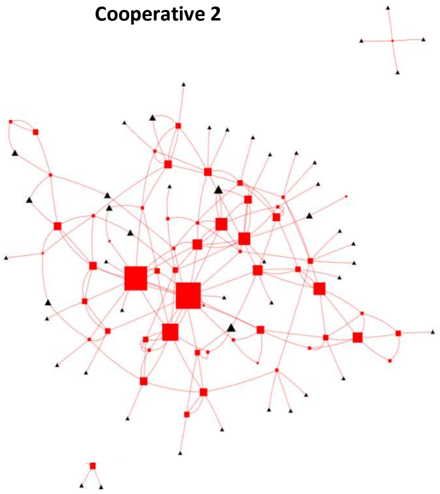
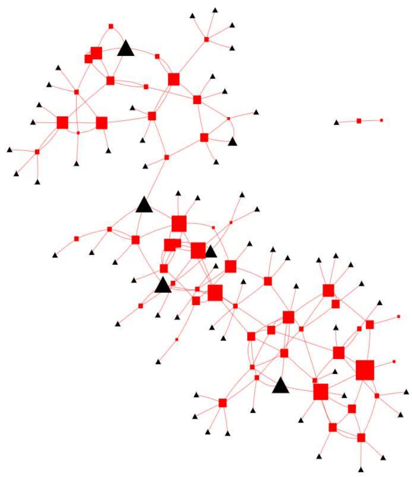
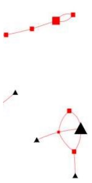


Figure 4.2a: Sociogram of Cooperative 1 network

Figure 4.2b: Sociogram of Cooperative 2 network

VBA 2





network

Figure 4.2d: Sociogram of VBA 2 network

Table 4.3: Network statistics

	Cooperative 1	Cooperative 2	VBA 1	VBA 2
Transitivity	0.25	0.19	0.2	0.15
Diameter	21	10	15	13
Centralisation	0.04	0.11	0.07	0.02
Edge Density	0.02	0.04	0.022	0.023

Cooperative 1 had the greatest diameter, meaning that information has further to travel if it is to pass throughout the entire network. It also had the second lowest centralisation score and the highest transitivity score, showing that the farmers are not centralised around a single actor, but are more likely to be in smaller, closely connected groups. These densely connected groups within the wider network can be identified in the sociogram for Cooperative 1 in Figure 4.2a. As cooperatives offer a venue for farmers to congregate together and form connections with individuals who may be socio-economically different to them, they may facilitate the development of bridging social capital which creates sparse networks and may explain the network structure of Cooperative 1.

In contrast, Cooperative 2 has the highest centralisation score, therefore a single farmer, or a small group of farmers, are at the centre of the network and are well connected to others in the network. Cooperative 2 also has the smallest diameter, meaning that information has less far to travel when passing through the network and that the network is relatively compact. This can be seen in the sociogram in Figure 4.2b as the large red square nodes in the centre of the network indicate farmers who have the most direct connections. This network also has the highest edge density and therefore has relatively more interconnections between members when compared to the other networks. These results show that the cooperative has high levels of bonding social capital, suggesting that the membership may be relatively homogenous.

Commented [XC13]: Don't feel this sentence is 100% clear...by "the cooperative" you mean members of the cooperative, or members of the "Cooperative network"?
Why didn't you test whether they are homogeneous??

VBA 1 has the second highest transitivity and centralisation, showing that within the network there are a few well-connected actors in the centre of densely connected sub-groups, but the entire network is not centred around them. VBA 1 also has the second highest diameter, meaning that these sub-groups are relatively spread out. In contrasts, VBA 2 has the lowest transitivity and the lowest centralisation score. This network is the least centralised around a single or few actors and has less densely connected subgroups when compared to the other networks in the study. The findings for the VBA networks may be reflective of the fact that there is no influential dairy organisation in the locations where many farmers can meet, or where a single farmer can become well-known and dominant across the whole network.

The network position of a lead farmer in F2F extension models can determine how far their knowledge will spread and who it will reach. In order to analyse the effect of network position on technology adoption within a network, the betweenness centrality and degree centrality of each node within the networks were calculated. Betweenness centrality is often used as a measure of influence in social networks as individuals with high betweenness centrality sit on important information pathways and are therefore crucial in the flow of information (Beaman & Dillon, 2018) (Nöldeke, et al., 2019). Betweenness centrality is very close to the concept of bridging social capital, which is vital in ensuring information is passed between sub-groups in a network (Valente & Fujimoto, 2010). Degree centrality is also commonly used as a measure of influence as a high degree centrality means the individual has the potential to directly pass on information to a high number of people (Mittal, et al., 2018) (Nöldeke, et al., 2019). Therefore, for each of the networks in this study, the five members with the highest betweenness and degree centrality scores were identified. If several network members had the same degree or betweenness centrality and were tied in fifth position, all those with the same score were included. T-tests were then carried out to test whether those with the highest betweenness and degree centrality scores had any statistically significant different characteristics compared to the rest of their network. The results for each network are shown in Table 4.4 and Table 4.5.

Table 4.4: Characteristics of those with the highest betweenness centrality scores compared to the rest of their networks

Betweenness Centrality								
	Cooperative 1		Cooperative 2		VBA 1		VBA 2	
	Top	Others	Top	Others	Top	Others	Top	Others
Age	53.4	55.5	61.8	54.5	52	49.8	57.4	54.6
Gender ꜝ	0.6	0.4	0.2	0.53	0.8	0.5	0.4	0.6
Farming years	18	14	24.8	18.6	16.6	12.4	12.6	19
Dairy Intensity	9***	24***	45	24	13	13.5	34*	18.7*
Farm Size	2.6	2	2.8*	2.2*	2	1.8	1.8	1.7
Internet Access ꜝꜝ	0.4	0.6	0.2	0.43	0.2	0.2	0.4	0.4
Amount of milk	25	40.2	77.8	34.5	14.2	16.5	39.4	23.2
Market distance	1.2*	4.8*	5.6	5.6	7.4	5.5	5.9	4
Forage use ꜝꜝ	0.6	0.8	1**	0.9**	0.4	0.4	1***	0.9***
Vaccines use ꜝꜝ	0.8	0.65	0.8	0.6	0.2	0.5	1**	0.8**
AI use ꜝꜝ	0.6	0.61	1**	0.43**	0**	0.06**	0.4	0.2

ꜝ 0 = male, 1 = female
ꜝꜝ 0 = no, 1 = yes
*p<0.01
** P<0.005
***p<0.001

Table 4.5: Characteristics of those with the highest ~~betweenness~~ degree centrality scores compared to the rest of their networks

Degree Centrality								
	Cooperative 1		Cooperative 2		VBA 1		VBA 2	
	Top	Others	Top	Others	Top	Others	Top	Others
Age	61.3	55.5	68.8***	54.5***	52	49.8	59.9	54.6
Gender †	0.5	0.4	0***	0.5***	0.2	0.5	0.6	0.6
Farming years	14.3	14.7	23.8	18.6	18.8	12.4	26.3	19
Dairy Intensity	20	24.5	26.6	24	16	13.5	27.2	18.7
Farm Size	2.1	2.0	2.6	2.2	1.8	1.8	2.2	1.7
Internet Access ††	0.7	0.6	0.6	0.4	0**	0.2**	0.4	0.4
Amount of milk	26.8	41.2	78.6	34.5	21.2	16.5	22.2	23.2
Market distance	3	4.8	5.6	5.6	2.8	5.5	3.7	4
Forage use †††	1***	0.8***	1**	0.9**	0.2	0.4	0.8	0.9
Vaccines use ††	0.5	0.6	0.8	0.6	0.8	0.5	1*	0.8*
AI use ††	0.8	0.6	0.8	0.4	0**	0.06**	0.4	0.2

† 0 = male, 1 = female
†† 0 = no, 1 = yes

*p<0.01
** P<0.005
***p<0.001

In Cooperative 1, the individuals with the highest betweenness centrality tended to be less dairy intensive, measured by how much of their income comes from dairy farming, and live closer to the market. In Cooperative 2, they tended to have bigger farms and were more likely to use forages and A.I. Similarly in VBA 2, there were higher levels of forage and vaccine use and higher dairy intensity amongst those with the highest betweenness centrality. In contrast, in VBA 1 those with a higher betweenness centrality were less likely to use A.I.

Commented [XC14]: What does this mean? Does it mean they are ineffective at disseminating tech? (I don't think so)

Commented [XC15R14]: Ignore this too, just me thinking

Individuals with higher betweenness centrality generally hold bridging positions which connect together subgroups within a network. This means that the individual tends to have more access to a range of information sources and knowledge, which is associated with higher technology use (Zhang, et al., 2020). The converse relationship that exists within VBA 1 will be explored in the discussion.

Those with the highest degree centrality were more likely to use forages in both cooperative networks and were more likely to older in Cooperative 2. They were less likely to have internet access or use A.I in VBA 1 and were more likely to use vaccines in VBA 2. Those with a high degree centrality have more direct connections, so similar to betweenness centrality will have more access to information sources which is associated with higher technology use.

To test whether there are any common characteristics across all the networks that are associated with higher betweenness and degree centrality, separate linear regression models were estimated using the data from all four networks. The results are shown in Table 4.6.

Table 4.6: Regression results for Betweenness and Degree Centrality

	Betweenness Centrality		Degree Centrality	
	Marginal Effects	S.E	Marginal Effects	S.E
Age	0.007	0.005	0.0201 ‘’	0.012’’
Gender ꝉ	-0.003	0.133	-1.03***	0.3***
Education ꝉꝉ	0.17’’	0.1’’	-0.125	0.23

Farming years	0.001	0.007	0.021	0.015
Member of a cooperative ⱡⱡⱡⱡ	0.32	0.21	1.405**	0.471**
Dairy Intensity	0.004	0.003	-0.007	0.007
Number cows	-0.021	0.047	-0.04	0.105
Farm Size ⱡⱡⱡ	0.05	0.09	0.386’’	0.210’’
Mobile Access ⱡⱡⱡⱡ	-0.552	0.4	1.4	0.904
Amount of milk (litres/day)	0.003*	0.002*	0.004	0.004
Market distance (km)	-0.015	0.009	-0.014	0.02
Number of dependents	-0.03	0.009	-0.084*	0.0414*
% of milk produced that is consumed	-0.004*	0.002*	-0.009*	0.004*
Member of an informal finance group ⱡⱡⱡⱡ	0.22’’	0.128’’	0.6*	0.291*
Received training from a cooperative ⱡⱡⱡⱡ	-0.18	0.169	0.097	0.38
Received training from a non-government extension officer ⱡⱡⱡⱡ	0.405’’	0.223’’	1.826 ***	0.504***
Received training from a government extension officer ⱡⱡⱡⱡ	0.224	0.178	-0.4490	0.404
ⱡ 0 = male, 1 = female ⱡⱡ 0 = no education, 1 = primary, can’t read, 2 = primary, can read, 3 = higher than primary ⱡⱡⱡ 1 = 0 to 0.5ha, 2 = 0.6 to 2.5ha, 3 = greater than 2.6 ⱡⱡⱡⱡ 0 = no, 1 = yes	Adjusted R-squared: 0.10 Residual S.E: 0.9479		Adjusted R-squared: 0.236 Residual S.E: 2.169	
’’p <0.01 *p<0.05 **p<0.01 ***p<0.001				

Commented [XC16]: Is this meant to be 0.1?

Those with a higher betweenness centrality tended to consume a lower proportion of the milk they produced, indicating they are selling more of their produce on the market which may offer an opportunity for them to form bridging connections that span different groups of farmers. Those with a higher degree centrality tended to be male, be a member of a dairy cooperative, have less dependents, consume less of the milk they produce, be a member of an informal finance group and have received training from a government extension officer. Being a member of a group, such as a cooperative or finance group will increase the number of contracts an individual has, and as with betweenness centrality, consuming less milk indicates more is sold which offers a chance for interaction with others in the dairy system.

4.6 Discussion

This study seeks to increase our understanding of the structure of farmers social networks, how information diffuses through them and what this means for technology adoption amongst smallholder farmers in SSA. AIS rely on access to information so farmers can learn about new innovations. This information transfer between research bodies, private companies and NGOs to smallholders has traditionally occurred through an extension model in which extension agents go out and train farmers directly. However, this approach has had mixed success resulting in a new paradigm of F2F extension emerging. Whilst the F2F approach has numerous benefits as farmers are more likely to trust information that comes from another farmer, it is more cost-effective as less farmers have to be directly trained, and the information may be continuously passed on through the network and reach more farmers, it relies heavily on farmer relationships and networks. A limited number of studies have used SNA to analyse the spread of information through farmer networks and have noted that who the information reaches, the speed it travels and its spread are all affected by the network structure (Beaman & Dillon, 2018) (Nöldeke, et al., 2019). To add to this emerging body literature, this study used data from dairy farmers in western Kenya in 2022 and created sociograms to analyse network structures. The results of the analysis and implications for F2F extension strategies are discussed in this section. It is important to note that the agricultural sector across SSA is heterogenous, spanning different climates, various produce and varying levels of market integration. Therefore, whilst some of the findings of this study can be generalised to apply to all F2F extension strategies, some findings, notably the socio-economic characteristics of those within the networks, are highly context specific to the dairy sector in western Kenya.

4.6.1 Network Structures

Bridging social capital is present in networks that are sparse and not densely connected. In these networks, certain individuals will hold positions that link smaller sub-groups of famers within the wider network together. Information can pass though these individuals into the sub-groups and increase their access to information and the related benefits. Higher levels of bridging social capital are therefore associated with increased information access. Cooperative 1 is an example of a network structure with high levels of bridging social capital as it has the largest diameter and highest transitivity. Diameter is measure of the length of the longest path between two nodes in the network and indicates how spread out the network is. Transitivity is a measure of the tendency of nodes within a network to cluster together into smaller sub-groups. Cooperative 1 is therefore relatively spread out, with smaller densely connected sub-groups being present within the wider network. The sociogram in Figure 2a shows this structure, with the sub-groups of farmers being connected to the wider network by one or two other farmers. The sub-groups are likely to be homogenous and have high levels of bonding social capital within them, and the farmers that link the sub-groups hold 'bridging positions' as they bridge the groups together. Bridging positions are often measured by betweenness centrality which is a measure of how many information pathways between other actors in the network an individual sits on (Beaman & Dillon, 2018).

The network structure of Cooperative 1 may have occurred as a result of the spatial distance between the connections. Table 1 shows that the average walking time between a connection in Cooperative 1 was around 90 minutes, which is nearly triple that of the VBA networks. Farmers who are spatially further apart are more likely to be heterogenous (Steeg, et al., 2010), and therefore the ties between the individuals are expected to be weaker and form bridging connections (Granovetter, 1973). However, these weak ties are extremely important in a network structure like that of Cooperative 1, as if information is not passed through them, it will not diffuse through the entire network (Borgatti & Halgin, 2011). In Cooperative 1, those that hold bridging positions and link parts of the network together did not have statistically higher technology use in any of the three technologies included in the study. As these individuals are important in the transfer of information, focusing on increasing their technology use and knowledge may help to increase overall adoption throughout the network.

Bonding social capital is used to describe the benefits that arise from being a member of a densely connected network which tends to be homogenous and inward facing (Lakon, et al., 2008). Whilst information may pass quickly and easily within bonded networks, it can be challenging for outside information to accepted or acted upon which can result in technology lock-in and non-adoption of technologies (King, et al., 2019). Cooperative 2 has the highest levels of bonding social capital out of the four networks in this study. It has the highest edge density, which is a measure of interconnection between network members and the lowest diameter, a measure of network compactness. This network structure is particularity interesting as the walking distance between connections is the highest out of all the networks, which often results in ties between members becoming weaker as spatial distance is linked to higher heterogeneity between actors (Steeg, et al., 2010).

Despite high levels of bonding social capital, new information and innovations are entering the Cooperative 2 network. Cooperative 2 has the joint highest level of forage adoption out of the four networks, measured by the percentage of network members using forages to feed their dairy livestock. It also has the second highest use of A.I, measured by the percent of network members who have used A.I. In bonded networks such as this, individuals who hold bridging positions, will be less influential as there are many pathways for information to travel via due to the high density of connections. However, individuals with the most direct connections, measured by degree centrality, will be more important in information transmission as they can spread knowledge directly to more network members, increasing the speed it passes through the network (Beaman & Dillon, 2018). The high centralisation score in Cooperative 2 and the sociogram in Figure 2b shows that the network is centred around a few individuals who have many direct connections and can be identified in Figure 2b as the largest nodes. Individuals with many connections are likely to be trusted by others within in their network (Cassidy & Barnes, 2012) and will therefore be able to influence the adoption decisions of the network. The technology use statistics in Table 2 support this finding, as the network members with the highest levels of degree centrality and therefore the most connections were statistically higher adopters of forage technologies when compared to the rest of the network, of which 90% were also adopters – the highest rate out of the networks in this study. It is therefore possible that the high levels of adoption amongst those with high degree centrality has resulted in information and knowledge of the innovation passing through the network, increasing uptake of the innovation across the network.

The structure of VBA 2 shows the existence of bonding social capital and bridging social capital. It has the second highest edge density, albeit only slightly higher than the other networks, and the second smallest diameter. This means that there are more interconnections between the farmers within the network and that the network is relatively compact when compared to the others in this study. Figure 2d shows that VBA 2 is made up of large sub-groups, larger than those in Cooperative 1, and the members of this sub-group are likely to be homogenous and have higher levels of bonding social capital. This network structure is potentially reflective of the fact that there is no dominant dairy organisation, such as a cooperative, which farmers travel to visit and therefore connections are centred around. As a result, many farmers will have strong relationships with farmers in their direct clique but may not have the opportunities to make contacts outside of this. However, some farmers do hold bridging positions between sub-groups, as can be seen in Figure 2d. These farmers offer potentially important information channels into the bonded groups and should be considered in any strategies that seek to diffuse innovations and knowledge.

VBA 2 had the highest percentage of members using vaccines. It also had the joint highest percentage of members using forages. The network members who had the most direct connections, and therefore the highest degree centrality, and the network members who held important bridging positions, and therefore the highest betweenness centrality, were all users of vaccines as shown in Table 2. 80% of the rest of the network were also adopters of vaccine, which is the highest level out of all the networks. This indicates that those with the most connections in the bonded sub-groups, and those who hold bridging positions, may be effectively influencing technology use in the network.

In VBA 1, there are a number of disconnected components in the network, i.e nodes and edges that aren't attached to the main network. Gaps between network components, such as these, have been described as 'structural holes' (Burt, 2001) and represent a lack of bridging social capital making the transfer of knowledge of new technologies to disconnected components challenging. VBA 1 also has the second highest diameter and second highest transitivity out of the four networks in this study. This network is therefore relatively spread out, with smaller densely connected sub-groups within it. These sub-groups will have high levels of bonding capital, which as previously mentioned can prevent outside information entering the groups or being acted upon. The existence of these sub-groups combined with the low levels of bridging social capital means outside information has no pathway into the sub-groups and has likely resulted in the low levels of technology adoption in the network, as shown in Table 3. Within VBA 1 the percentage of network members using each of the three technologies is lower than all the other networks. VBA 1 also has the lowest overall social capital score. Low social capital is often linked to low technology adoption (Husen, et al., 2017) (Isham, 2002) and the findings of this study support this.

4.6.2 Influential People

Individuals with the highest betweenness centrality hold important bridging positions and are therefore well placed to ensure information spreads across the entire network, especially within networks with a large diameter and high transitivity, such as Cooperative 1. In these networks, selecting individuals in bridging positions to be lead farmers may help ensure that information reaches sub-groups of farmers. The evidence from VBA 2 supports this claim as individuals with a higher betweenness centrality were all adopters of both forages and vaccines, which may have influenced the adoption of these technologies across the wider networks as VBA 2 has the highest levels of forage and vaccine adoption out of the networks in this study.

Commented [XC17]: test whether this is the case, or it just happens to be that the people in these bringing positions are connected to individuals such that their combination makes the spread of tech from the other into the bridger higher, but not necessarily the other way around.

Commented [XC18R17]: Ignore this - me sorting out dissertation thoughts

In order to understand the characteristics of those who hold these bridging positions, a regression was estimated, and the results are shown in Table 4.6. It shows that individuals with higher levels of betweenness centrality, who hold bridging positions, tended to produce more milk and to consume less of it. This is likely to mean that they sell their milk and are therefore more market orientated. Farmers may sell either to cooperatives or at markets directly to buyers. Both these institutions offer an opportunity for farmers to socialise and develop new contacts with other farmers or value chain actors who may be different to them in terms of socio-economic status or may live further away. As a result, these farmers form important relationships that connect groups of heterogenous farmers together, resulting in them holding bridging positions in their networks. Previous studies have supported this finding, with farmers in Kenya who had higher levels of social capital tending to be more commercially orientated (Korir, et al., 2015).

Individuals with the highest degree centrality have the most direct connections in the network and are often trusted and influential meaning the information they pass on is likely to be regarded more highly (Cassidy & Barnes, 2012). Farmers who had a higher degree centrality were more likely to be male, be a member of a cooperative, have fewer dependents, consume a lower proportion of the milk then produce, be a member of a finance group and have received training from non-government extension officers. Some of these characteristics may be highly specific to the Kenyan dairy sector, for example smallholder dairying in Kenya is often led by males which may result in other farmers seeking information from males (Kirui, et al., 2021) and this may not be true in other African countries. However, being a member of groups such as cooperatives and finance groups increases the potential for an individual to meet other farmers and therefore develop more connections and this is likely to be true in all contexts. The results of the regression also confirm previous findings that women with children are often marginalised in Africa (Othman, et al., 2021), as Table 4.6 shows that these women and those with a higher number of dependents are likely to have to least direct connections.

4.6.3 Implications for F2F extension strategies

This study has shown that the informal network structures of farmers are context specific and will have differing levels of bonding and bridging capital within them. However, some general conclusions and suggestions for future F2F extension strategies can be made.

Firstly, the cooperative networks span a larger geographical distance than the VBA networks, therefore that any information that passes through these networks has the potential to reach more farmers. Being a member of a cooperative was also associated having more connections to other farmers. Focusing F2F extension strategies in cooperatives or selecting a lead farmer who is already a member of a cooperative, may therefore offer an opportunity for knowledge of innovations to spread to a greater number of farmers. However, Cooperative 1 and Cooperative 2 have vastly different network structures. Cooperative 1 relies heavily on individuals in bridging positions, who are important in passing information between network sub-groups, to diffuse knowledge across the whole network. In contrast, Cooperative 2 is densely connected and therefore individuals with the most connections are likely to have more influence over the spread and speed of knowledge diffusion.

Commented [XC19]: Assumes constant population (or rather farmer) density and equivalent dairy farming capacity.

The VBA networks also differ in structure. Evidence from VBA 1 suggests knowledge transfer and technology adoption is not as effective in networks with low social capital and it may therefore be challenging for F2F extension to operate in these areas. However, high technology adoption and higher levels of social capital in VBA 2 show that both bonding and bridging social capital can exist without cooperatives facilitating farmer interaction. F2F extension may be more important in these locations as farmers may be unable to access information from other sources. It is therefore beneficial for F2F extension projects to identify a minimal level of social capital in the location they operate to ensure they are successful.

Deciding which farmers to select as lead farmers in F2F extension strategies will depend on the network structure. In networks with high levels of bridging social capital, identifying individuals with high levels of betweenness centrality and therefore hold bridging positions in the network, can help ensure information is passed between different groups of farmers. Farmers with a high degree centrality, and therefore the most connections, can also be important in networks with bridging social capital as they can transfer information through their bonded sub-group, and are important in bonded networks as they can pass information on directly to more people. It is therefore recommended that F2F extension projects should develop an understanding of the network structure in their location to ensure they target influential individuals to be lead farmers. If it is not possible to map out the social networks, identifying individuals who regularly attend markets or are members of farmer groups or other informal groups to be lead farmers increases the likelihood that they hold influential positions in the network.

Chapter Five: Can government policy drive the creation of successful agricultural cooperatives? Evidence from Rwanda.

5.1 Summary

This thesis chapter seeks to analyse if social networks and the social capital they generate can be created through government policy. Chapter 3 of this thesis showed that Ethiopian AIS are dominated by public sector actors. This is likely to have prevented high levels of agricultural technology adoption within the country as farmers' access to information is restricted and the government can dictate what technologies are the focus of research and promotion strategies. A key policy that the Ethiopian government has pursed to try and encourage technology adoption and agricultural development has focused on the creation of agricultural cooperatives (Abebaw & Haile, 2013). Agricultural cooperatives are a form of collective action in which farmers work together using social capital to overcome their size related disadvantages. They are also an important venue for farmers to interact and share knowledge and learn about new innovations. A key issue with policies that focus on the creation of cooperatives is that the cooperatives then tend to be organized by top-down external agents to meet the objectives of governments as opposed to being self-organised by the farmers themselves (Sebhatu, et al., 2020). As a result, there are often high levels of distrust and corruption (ibid.).

The Government of Rwanda approaches agricultural development in a similar to way to Ethiopia. They intervene heavily in the sector and have introduced highly prescriptive policies to try and develop Rwandan agriculture. As with Ethiopia, the Government of Rwanda has focused on cooperatives as vehicle for development. This chapter therefore uses data collected from Rwanda in 2018 to understand whether government driven agricultural cooperatives can generate genuine social capital between members and have positive effects on innovation adoption and the economic position of smallholders.

In this chapter, the levels of social capital across six agricultural cooperatives within Rwanda are estimated. Social networks maps are then created to understand the different network structures and the power dynamics within the cooperatives. Finally, the relationship between social capital and economic empowerment is explored using statistical models. The results provide support for the idea that government-initiated cooperatives can result in the production of social capital between members. This social capital has a positive effect on the level of economic empowerment cooperative members experience and will therefore likely have a positive effect on innovation adoption. However, due to the marginalisation of certain members and the dominant role of cooperative leadership, the sustainability or inclusivity of these cooperatives should be questioned.

5.2 Introduction

Agricultural cooperatives are often used as a mechanism for increasing the economic empowerment of rural farmers and promoting agricultural development. Traditionally cooperatives are formed by a group of producers working together to increase their bargaining power and to access larger markets. In sub-Saharan Africa (SSA) and much of the developing world, these producers are typically smallholder farmers. Cooperatives are a form of collective action that rely on a base of social capital where farmers have shared norms, trust each other and act reciprocally. The success of agricultural cooperatives (Kustepeli, et al., 2020) (Akul, et al., 2018) has led to many governments introducing policies that actively promote their creation and oversee their operation. However, evidence on the effectiveness of these policies is mixed (Cox & Le, 2014; Eyo, 2008; Dejene & Getachew 2015) with critics arguing that they are attempting to 'socially engineer' relationships and may fail to generate any real social capital as the underlying trust and reciprocity, that are crucial building blocks, do not exist (Portes & Landolt, 2000).

The Government of Rwanda (GoR) has pursued a prescriptive and authoritarian approach to the agricultural sector which has included the formation of agricultural cooperatives through state coercion (Huggins, 2014). Whilst not all cooperatives in Rwanda have been created by the state, a previous study of a random sample of 251 maize and horticultural cooperatives showed that all the maize cooperatives (n=117) and half the horticultural cooperatives (n=134) were government initiated (Verhofstadt & Maertens, 2014). Those that are not state created are usually founded by local elites with strong connections to the authorities (Huggins, 2014). This study therefore uses data collected from Rwandan agricultural cooperatives to explore whether successful agricultural cooperatives and the social capital that underpins them can be effectively created through state intervention. The rest of the introduction discusses the theory behind social capital in agricultural cooperatives and the Rwandan context. This is followed by a methods section which details data collection and the analytical methods used for the data analysis. Finally, the results of the data analysis are presented and discussed.

5.2.1 Social Capital in Agricultural Cooperatives

Smallholder farmers face many market failures such as high transaction costs, imperfect information and barriers to entry into large markets (Gyau, et al., 2014). These market failures can prevent the development of agricultural sectors in countries that are dominated by small scale production. As a result, farmers are not able to maximise their incomes and may be unable to escape the poverty trap. To correct some of these market failures, agricultural cooperatives allow farmers to increase their ability to collectively bargain and leverage group buying or selling. Facets of successful cooperatives have been explored by many authors (Abate, 2018; Meador, et al., 2016; Wedig & Wiegratz, 2017) with one key element of success being the existence of strong social capital. Social capital is defined as the ‘connections among individuals -social networks and the norms of reciprocity and trustworthiness that arise from them’ (Putnam, 1993). These connections can be used by the individuals to improve their economic circumstances in several ways. They can reduce transaction costs due to trust and social sanctions removing the need for legal processes (Woodhouse, 2006). They can also facilitate the development of group norms allowing the effective governance of the commons

(Ostrom, 1994) and they can result in trusted and reliable information being shared between peers.

In the context of agricultural cooperatives, the existence of social capital allows farmers to trust one another and their leadership, who are typically drawn from the general membership. Members will be more willing to sell their produce to the cooperative, increasing its collective bargaining power (Akul, et al., 2018) and trusted information regarding new innovations, buyer markets and training opportunities will also flow more freely between members. As a result of these factors, cooperative members will experience higher levels of economic empowerment as they hold more knowledge which they can convert into increased productivity, they have the potential to sell their produce at higher prices and the cooperative itself can offer a platform in which their voices can be heard.

In some circumstances cooperatives fail and studies have identified many internal and external causes of failure including free-riding, bad management, low trust between members and general noncompliance to cooperative rules. Many of these are a direct result of low levels of social capital as members may not be bonded enough for the threat social sanctions to prevent free riders, enforce compliance and hold management accountable. As a result, 'side-selling' occurs in which farmers choose to sell to buyers other than their cooperative (Getnet & Anullo, 2012). Side selling allows farmers to gain benefits from being a cooperative member, such as access to inputs and training, but also allows them to benefit individually by selling their milk to private buyers (Shumeta, et al., 2018). As a result, there may be less care given to milk quality sold to the cooperative and less interest in the operation of the cooperative (ibid.). These factors can affect the sustainability and profitability of cooperatives and undermine leadership.

Social capital is not easily created, nor does it simply occur as a result of being a member of a cooperative. Portes and Landolt (2000) use examples from Latin America to show how attempts to create social capital in a development setting can fail. They argue policy approaches to social capital have been ‘over-optimistic’ in trying to create new networks and forced trust from scratch. These fail because individuals in the groups tend to free-ride, the networks diminish once external actors leave and many initiatives use social capital as an alternative to other forms of capital and there is a limit to what groups can achieve when they are resource poor. Similar concerns are echoed by DeFilippis (2001) who argue that we cannot view attempts to create social capital as a ‘win-win’ endeavour, but rather we need to build on existing networks and ensure groups have power and control over other forms of capital. Another key issue prominent within externally enforced cooperatives is the leadership becoming dominating and self-serving. In these circumstances the cooperative may work towards the aims of the leader and not those of the group (Portes & Landolt, 2000).

5.2.2 The Rwandan Context

The Rwandan genocide in 1994 resulted in a complete collapse and subsequent overhaul of Rwandan politics. The genocide, carried out by neighbours on one another, destroyed any social cohesion that may have existed and all institutional governance became non-existent almost overnight. Beidermann (2015) notes that this was a ‘window of opportunity for deep-seated reforms’ in the country, something that the Rwandan Patriotic Front (RPF) took full advantage of after they successfully ended the genocide and took power. The new government introduced strong anti-corruption legislation and adopted a highly hierarchical structure which instilled party cohesion and attracted investment from international communities (Biedermann, 2015). As a result, Rwanda has experienced vast improvements in healthcare, education and agriculture.

One of the flagship policies the GoR has adopted since 1994 is the ‘National Decentralisation Policy’ that seeks to empower local populations and communities and make them accountable for their own development activities (Colletta & Cullen, 2000). The policy, which was revised in 2012, promotes downward accountability. Examples of programmes which have arisen from this policy include the ‘ubudehe / VUP’, which encourages participatory planning within communities and provides microfinance, and ‘Umuganda’, which is mandatory community work that citizens must take part in once a month (Hasselskog & Schierenbeck, 2015). There is considerable debate over whether such policies do actually empower local communities or whether it is simply an agenda by the political elite to use local spaces to promote loyalty (ibid) and a tool for controlling local populations (Hasselskog, 2016).

Agriculture is an area where the GoR has acted in a starkly authoritarian manner. Economic growth in Rwanda has been impressive over the past 20 years although the Gini coefficient shows inequality has been rising at a substantial rate (Huggins, 2014). The rural populations who are heavily reliant on agriculture have suffered from a shortage of land due to population density and the limited use of both fertilizers and improved seed has resulted in low productivity (Musabanganji, et al., 2016). Aware that these tensions may present significant problems in the future, the GoR has laid out a long-term strategy for the agricultural sector which seeks to increase food security whilst converting Rwanda’s agriculture into a commercialised market-orientated sector.

Policies to achieve the desired growth in the agricultural sector have included the ‘Crop Intensification Programme’ where the government selected six crops based on comparative advantage and ‘encouraged’ their production in a uniform manner across the country (Cioffo, et al., 2016). GoR also introduced land reform policies which allowed farmers to retain their land rights but stated that they must use their land in a productive way by synchronising crops and methods (ibid). Most relevant to this study, however, has been the push from the GoR for farmers to join cooperatives.

The creation of agricultural cooperatives is central to agricultural reform. According to Rwanda Cooperative Agency, the number of cooperatives has nearly tripled from below 3,000 in 2010 to over 8,000 in 2018 (Rwanda Cooperative Agency , 2018). Whilst some cooperatives have formed organically from voluntary organisations, many have been created directly by the state or local elites who are associated with the authorities. Huggins (2014) quotes a Rwandan farmer stating that ‘you cannot differentiate between the cooperatives and the state institutions. The leaders [of the co-ops] are often the local authorities’. He also notes that the pressure to form cooperatives has resulted in the sharing of resources between those who do not trust each other and that in some areas cooperatives can be highly controlling and will not let farmers sell to other buyers. At a higher level, Rwandan cooperatives are organised into unions which tend to be where important issues and decisions are debated and made (Republic of Rwanda: Rwanda Cooperative Agency, 2018).

5.3 Hypothesis and Research Question

Based on previous studies of Rwandan agricultural cooperatives, it appears that social capital levels are low, with members having little autonomy or power over the direction or actions of their group. One study reported a lack of trust between members (Huggins, 2014), whilst another found that farmers did not feel any ownership over the cooperative (Moon & Lee, 2020). There is also evidence that leadership fail to listen to the members and enforce bad decisions on farmers resulting in a loss of revenue (Cioffo, et al., 2016). Based on these previous findings, it was hypothesised that:

The GoR has failed to create agricultural cooperatives that operate on a basis of social capital, resulting in members experiencing lower levels of economic empowerment.

This hypothesis was tested by answering the following research questions:

What are the levels of social capital in a sample of six cooperatives?

Does this social capital effectively translate into economic empowerment?

To answer these questions and test the hypothesis, data collected in Rwandan in 2018 was analysed. The methods and results are discussed in the following sections.

5.4 Data Collection and Methods

5.4.1 Data Collection

The data used in this study was collected by a research team in a two-stage process during the spring and summer of 2018. The first stage consisted of focus groups held in location with members of the cooperatives and leadership. In addition to focus groups, key-informant interviews were held with policymakers in the Rwandan Government and representatives of the Ministry of Agriculture and Animal Resources. These focus groups and key-informant interviews were used to develop a survey tool and to add a contextual understanding of the intricacies around cooperative members and leaders' understanding of one another (i.e. their roles and responsibilities). The second stage consisted of a cross-sectional in-person survey.

Workshops were held with six cooperatives (four dairy and two primarily maize). These cooperatives were identified and included in the study as they fitted criteria around gender, geographical representation and membership size. Workshops were held onsite at each cooperative location. The research team attended each workshop and translation from Kinyarwanda to English was done by locally hired translators who accompanied the research team. Members of the cooperative board, along with several general members, participated in all workshops. All but two workshops were led in part by the cooperative president and where absent, the cooperative vice-president attended. In total, between ten and fifteen people attended at each location. There was a good distribution of participants in terms of age at each workshop and the maize cooperative workshops were attended by a roughly even split of women and men. Only men attended the four dairy workshops.

The survey sample was developed using a simple-random probability by randomly selecting *n* participants from a membership list of each cooperative. Surveys were enumerated by local people, who were trained by a regional expert with experience conducting social scientific surveys in rural areas of Rwanda. Enumerators also entered each completed survey into a global database. This database was sent to the research team who further coded and cleaned the data in preparation for statistical analysis.

5.4.2 Empirical Methods

This study uses confirmatory factor analysis, social network analysis and a stepwise multiple linear regression to analyse the data. Initially, two factor analyses were carried out on a series of Likert-scale questions to create two latent variables: social capital and economic empowerment. The Likert-scale questions asked the respondent to either rank how well they agreed with a statement on a scale of 1 to 5, with 1 being 'strongly disagree' and 5 being 'strongly agree', or they asked the respondent how well certain objectives were being met, again on scale of 1 to 5. In these questions, 1 represented 'very poor' and 5 represented 'excellent'. Likert-scale questions are commonly used in social science disciplines but have some biases and issues that need to be considered.

Firstly, Likert-scales are arbitrary in the sense that each response has no objective numerical value and the value assigned to the Likert-scale is determined by the survey designer. Therefore, the distance between two successive points is not uniform and may be viewed differently depending on the individual. To overcome this issue, ensuring the Likert-scale is symmetric with a midpoint can assist the respondent in viewing either side of the mid-point as equidistant. This study uses a 5-point Likert-scale, meaning there is a clear mid-point which respondents can use as a frame of reference. For the statement questions, symmetrical language is used with 'strongly agree' and 'strongly disagree' being the two extremes. This also helps respondents view the intervals between points as equal. Due to the design of these Likert-scale questions, with a clear mid-point and clearly defined extremes on either side, it is acceptable to treat these scales as interval.

Secondly, Likert-scale questions tend to suffer from central tendency bias in which the respondent is more likely to choose a central point on the scales rather than either of the extremes. The most cited way to overcome this form of bias is to explain the question and ranking system to the respondent as the chances of selecting a middle answer increase when the question is not fully understood (Mangione, 1995). Whilst the questions in this study were each prefaced with a clear explanation, the existence of central tendency bias must be considered when reviewing the data results.

As discussed in the introduction, social capital is represented by trust and reciprocity. Questions relating to trust and reciprocity were therefore used to create the latent social capital variable. These questions focused on trust in leadership, including leadership at the union level and general attitudes toward the cooperative. To confirm that the questions selected are measuring the same factor, the Cronbachs alpha was calculated which returned a value of α = 0.74 indicating a high level of internal consistency between the questions. A Kaiser-Meyer-Olkin (KMO) test was then used to test the proportion of variance that might be caused by underlying factors. The test gave a Measure of Sampling Adequacy statistic (MSA) of 0.81. An MSA over 0.80 means a factor analysis is appropriate. Finally, a factor analysis was carried out, the results of which, along with the Likert-scale questions and their relevance to social capital, are shown in Table 5.1.

To create the final variable, social capital, the values for each question were multiplied by their factor loading and then summed together. The summed number was then transformed onto a scale of 0 to 1, with 1 being the highest possible value for social capital.

Table 5.1: Factor analysis for social capital variable

Question	How they measure social capital	Mean	s.d	Factor Loading	h^2
The information my cooperative leaders receive from union leaders is trustworthy	Measures how much trust members have in the information they receive. If information is regarded as trustworthy, this indicates the presence of social capital.	2.87	0.78	0.748	0.559
My cooperative leaders listen and respond to their members	Leaders responding and listening to their members can be seen as a form of reciprocity. Members contribute to the cooperative,	3	0.6	0.701	0.492

	and in return leaders listen and respond to their needs.				
My cooperative leaders communicate important information about the union to me	This is a measure of both trust and reciprocity. General members are trusting leaders to communicate important information to them, but leaders are reciprocating members commitment to the cooperative through keeping them informed	2.9	0.75	0.749	0.561
Membership in a union is an important way for a small farmer to have his/her voice heard	High levels of social capital in a cooperative, or similar organisation, allow farmers to collectively come together and have more economic weight and influence in comparison to a single farmer. If a member perceives being a member of a union allows them to have their voice heard, it is likely that a base of social capital has resulted in this.	1.6	0.54	0.438	0.192
My cooperative leaders have the knowledge and experience to manage my cooperative well	If members perceive the cooperative leaders to be qualified for their position, they are likely to have more trust in the leadership indicating higher levels of social capital .	2.5	.56	0.592	0.351
My cooperative encourages women to hold leadership positions	Encouraging woman to be in the cooperative leadership shows respect and trust in a traditionally marginalised group. It also implies female members will feel more included and respected in the group, showing higher levels of social capital.	2.5	0.51	0.565	0.32
Test of the hypothesis that 1 factor is sufficient. x^2 = 34.49 on 9 degrees of freedom. p-value = 7.32e-05					

To create the economic empowerment variable, six Likert-scale questions were used. It should be noted that these questions refer to the union rather the cooperative. Unions are the level above cooperatives in government hierarchy and are responsible for delivering training, finance and market access to farmers via the cooperative. It is the role of the cooperative to communicate to the union their members needs and demands, which the union then acts upon. The Cronbachs alpha of the questions was 0.7 and the KMO test showed the MSA to be 0.84. This confirmed that a factor analysis was appropriate. The results of the factor analysis, the questions used to create the factor and their relevance to economic empowerment are shown in Table 5.2. As with social capital, the responses to each question were multiplied by their factor loading, summed together and then converted onto a scale of 0 to 1, with 1 representing the highest possible value for economic empowerment.

Table 5.2: Factor analysis for economic empowerment variable

Question	How they measure economic agency	Mean	s.d	Factor Loading	h^2
How well does the union provide access to information?	Having access to information increases the ability of members to make informed decisions. This increases their economic empowerment.	3.74	1.2	0.778	0.606
How well does the union provide market access?	Providing access to markets increases the ability of members to be able to sell their produce and at higher prices. This may also increase their number of potential buyers and provide members with more economic empowerment in terms of higher income and more choice.	3.5	1.2	0.783	0.612
How well does the union provide access to finance?	Finance access can help members invest in their farms which can increase their productivity and provide them with more empowerment.	3	1.4	0.629	0.395
How well does the union provide inputs?	The use of inputs increases productivity, again increases members potential earn more money.	3.2	1.42	0.651	0.423
How well does the union do advocacy?	Advocacy on behalf of members increases the chances of their voices being heard, which increases their influence and therefore their economic empowerment.	3.7	1.16	0.777	0.603
How well does the union provide	Extension services allow farmers to learn new practices and access new	3.4	3.3	0.284	0.081

extension services?	information, which they can then convert into productivity gains and increase control of their economic situation				
Test of the hypothesis that 1 factor is sufficient. $x^2 = 17.3$ on 9 degrees of freedom. The p-value = 0.0442					

After creating the relevant variables using factor analyses, a stepwise linear regression was chosen to test whether social capital, or any other relevant socio-economic factors, were determinants of economic empowerment. A stepwise model is used when the impact of different variables within the model need to be tested sequentially as it is unclear which are relevant (Mundry & Nunn, 2009). It was used in this instance as socio-economic variables were deemed to be important in determining economic empowerment, yet which variables were unknown. A combination of backwards elimination and forward selection was used in the stepwise process (Henderson & Denison, 1989). The backwards elimination allowed for the identification and removal of spurious variables. During this stage, all the socio-economic variables were initially included and then the weakest predicators, notably gender and member type (whether leader or general member), were deemed irrelevant to the model and dropped. At this stage, variance inflation factors (VIF) were calculated to test for multicollinearity between the independent variables. The VIF for each variable was between 1 and 2 indicating that high multicollinearity is not present. The forward selection process was then used to test interaction effects on the model and those which were identified as important were included.

The final model was calculated using:

$$EE = \beta_0 + \beta_1 E + \beta_2 A + \beta_4 CT + \beta_5 CS + \beta_6 SC + \beta_7 A * CY + \beta_6 cS * CY + \varepsilon$$

Where EE is the latent variable economic empowerment, E represents education levels and A represents age. CS represents amount of produce the member sells to the cooperative, with 1 indicating none and 5 indicating 76% or more. CT is the type of cooperative, either maize of dairy and SC is the latent variable social capital.

Finally, social network analysis was used to map out the relationships between the general membership and leadership of the cooperatives. Survey respondents were asked to select up to three members of the leadership that they would go to for information regarding the cooperative. The answers were then used to produce a sociogram which is made of nodes and edges. Nodes represent the actors in a social network, which for this study are the cooperative leaders and members, whilst edges represent the type of relationship between the nodes, which for this study is the transfer of information. Two network statistics were then calculated using the sociogram: the degree centrality of each node and the total centralisation of the network. The degree centrality is a measure of how many edges are incident on a node and the total centralisation of a network is a measure of how centred the network is round a single, or a few, individuals. The centralisation of a network is given on a scale of 0 to 1, with 0 indicating no centralisation.

5.5 Results

5.5.1 Descriptive Statistics

The attributes of the respondents from each cooperative are shown in Table 5.3. The maize cooperatives had a higher proportion of women when compared to the dairy cooperatives. Except for Dairy 1, primary education was the most common education level. In Dairy 1, a third of respondents had no formal education and could not read. Dairy 3 had the highest proportion of younger members (18-34) in the cooperative and also had the highest proportion of new members, with 50% having only been members for 0-4 years. Maize 2 had the highest proportion of older members and had the highest proportion of longer serving members. Dairy 2 had the highest average level of social capital and both Maize 1 and Maize 2 had the highest average levels of economic empowerment.

Table 5.3: Descriptive statistics of the cooperatives

		Dairy 1	Dairy 2	Dairy 3	Dairy 4	Maize 1	Maize 2
	n	**27**	**27**	**40**	**28**	**40**	**44**
		% of cooperative					
Age	18-24	0	3.7	0	0	5	0
	25-34	14.8	25.9	37.5	17.9	25	11.4
	35-44	33.3	11.1	15	28.6	30	22.7
	45-54	22.2	29.6	20	32.1	22.5	36.4
	55+	29.6	29.6	27.5	21.4	17.5	29.6
Gender	Male	85.2	81.8	67.5	67.9	45	59.1
	Female	14.8	11.1	32.5	32.1	55	41
Education	No school education, can't read	33.3	*18.5*	5	14.3	10	4.5
	No school education, can read	*18.5*	25.9	2.5	25	0	9.1
	Some primary education	22.2	29.6	57.5	39.3	77.5	81.8
	Some secondary education	25.9	25.9	35	21.4	12.5	11.4
Years in Coop	0-5	*7.4*	*11.1*	50	39.3	20	2.3
	5-9	85.2	81.8	10	42.9	35	38.7
	10-14	*3.7*	*0*	37.5	17.9	37.5	59
	15-19	*3.7*	*0*	2.5	0	7	0
		Average in cooperative					
Social Capital	Mean	0.82	0.84	0.66	0.86	0.84	0.85
	Std. Deviation	0.12	0.1	0.17	0.12	0.09	0.11
Economic Empowerment	Mean	0.44	0.46	0.32	0.44	0.51	0.52
	Std. Deviation	0.08	0.07	0.22	0.09	0.09	0.07

A boxplot showing the distribution of the social capital variable is shown in Figure 5.1. The boxplot shows that whilst the median level of social capital is similar in all cooperatives apart from Dairy 3, the distribution of the social capital variable differs between cooperatives. Dairy 4 has the highest median score for social capital and the shortest interquartile range indicating that most of the members of the cooperative have social capital levels that are closely grouped together. There are however two notable outliers, represented by the dots on the graph, whose social capital levels are much lower than the rest of the cooperative. In contrast, Maize 6 has the greatest interquartile range showing that the members of this cooperative have social capital levels that spanned a wider range.

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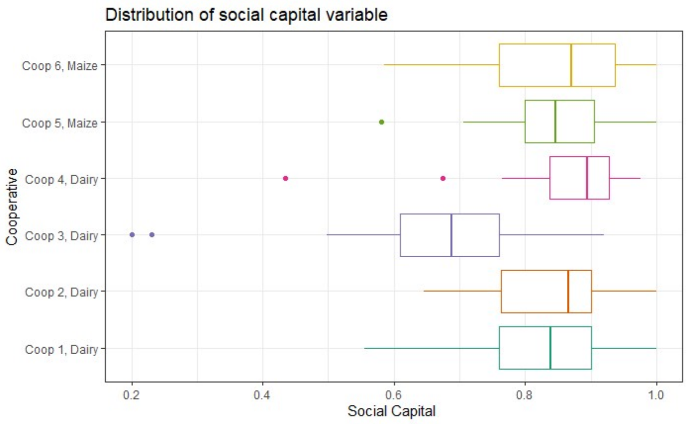

Figure 5.1: Distribution of the social capital variable by cooperative

The distributions of the latent economic empowerment variable are shown in Figure 5.2. With the exception of Dairy 3, the median economic empowerment for the cooperatives was around 0.5. Dairy 3 had a much lower median value and a greater interquartile range with the median skewed to the left. This indicates that the economic empowerment values in this cooperative are spread out, but with the lower values more closely grouped together.

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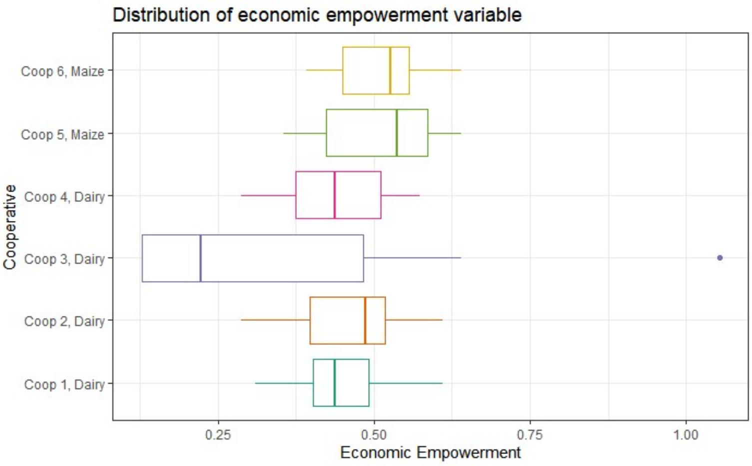

Figure 5.2: Distribution of the social capital variable by cooperative

The sociograms for each cooperative are shown in Figure 5.3. In some cooperatives there were missing responses to this question and therefore the number of nodes in each network may not be the same as the number of total survey respondents. In the sociograms, the blue nodes represent leadership members and the red represent the general membership. In each of the networks, there is one, or a few, blue nodes at the centre which the other nodes surround. These nodes in the centre are the most well-connected leaders and are likely to have a lot of influence over the network. The data in Table 5.4 shows that the President of each cooperative has the most direct connections and that the leader position with the second highest number of connections changes between cooperatives. The overall centralisation score was lowest in Dairy 1 and Dairy 2 cooperatives and highest in Dairy 4.

Figure 5.3: Sociograms for each cooperative network

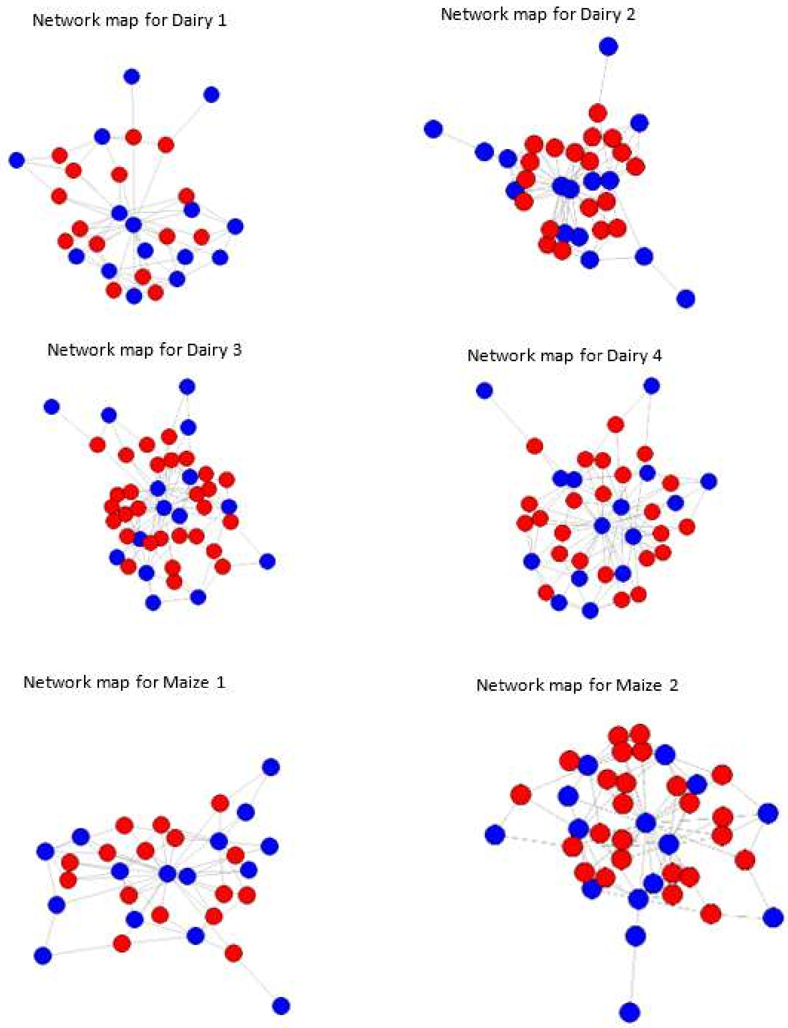

Table 5.4: Degree centrality and centralisation of each cooperative network

	Dairy 1	Dairy 2	Dairy 3	Dairy 4	Maize 1	Maize 2
	Degree centrality					
President	19	21	30	28	22	28
Vice President	9	19	19	7	9	10
Secretary	8	7	12	8	6	14
Advisor	5	8	9	12	6	9
Auditor	12	13	5	13	10	9
Manager	3	NA	7	NA	NA	1
Mobilizer	NA	1	2	4	NA	NA
Accountant	5	4	NA	15	7	10
Extension	1	1	NA	2	NA	2
Veterinary	1	1	NA	NA	2	NA
Agronomist	NA	NA	NA	1	NA	4
Zone Leader	NA	NA	NA	NA	2	2
Site Leader	NA	NA	NA	NA	NA	NA
	Centralisation					
	0.44	0.44	0.59	0.62	0.59	0.60

5.5.2 Model results

The results of the stepwise linear regression are shown in Table 5.5. The results show that the type of cooperative, i.e whether it is dairy or maize, the number of years an individual has been a member of the cooperative and social capital all have a statistically significant effect on economic empowerment. Cooperative type was coded as a dummy variable with dairy being 0 and maize being 1. The positive effect that cooperative type has on economic empowerment shows that members of maize cooperatives tend to have a higher level of economic empowerment. The positive effect between years in the cooperative and economic empowerment was small, with the level of economic empowerment increasing by 0.01 for every additional year of membership. The effect of social capital on economic empowerment was larger, with a one-point increase in social capital being associated with a 0.32-point increase in economic empowerment.

Table 5.5: Results of the stepwise linear regression

Variable	Estimate	Marginal effect	Std. error
Education	-0.09	-0.01	0.01
Age	0.002	0.0003	0.0007
Cooperative type	0.07***	0.07***	0.02
Percentage sold to coop	-0.01	-0.01	0.01
Social Capital	0.52***	0.32***	0.07
Years in Cooperative	0.04**	0.01**	0.003
Age * Years in Cooperative	-0.0002		0.0002
Years in Cooperative * Social Capital	-0.27		0.01
Residual standard error: 0.1088 on 148 degrees of freedom R^2 = 0.4235 p-value = 2.88e-16 *** = significant at 0.001 ** - significant at 0.01			

5.6 Discussion

This study was motivated by the need to understand whether attempts by governments to create agricultural cooperatives can result in the generation of social capital which is key to their success. Using Rwanda as the case study, six agricultural cooperatives were analysed providing insight into the levels of social capital, their network structure and the amount of economic empowerment members of the cooperatives were experiencing. Social capital can be transformed into economic empowerment via cooperatives as it can increase information sharing resulting in farmers having more knowledge, increase farmer commitment resulting in more produce being sold to the cooperative and therefore more bargaining power and it can offer a platform where individual farmer voices can be heard.

Previous studies on Rwandan agricultural cooperatives have identified low levels of social capital and raised this as a concern for their long-term sustainability and outcomes (Ansoms, et al., 2018). Whilst this study does not have a counterfactual or baseline against which social capital levels can be compared, all but 1 of the cooperatives studied had social capital scores of over 0.80. This shows that members felt mostly positive feelings towards the cooperative and leadership and likely indicates high levels of social capital. Figure 5.1 does show that the social capital values within each cooperative were spread across a range and that three of the cooperatives had outliers whose social capital was much lower compared to the rest of the group. This reveals that certain individuals may be more marginalised in the group and as a result may not experience the same level of benefits from the cooperative when compared to others. Whilst this study does not go into detail on who these marginalised individuals may be, previous studies have found that they tend to be women and youth (Orrnert, 2018) (Burnet, 2003).

Traditionally cooperatives come from grassroots organisations, run by members who already have a basis of social capital between them. As a result, social sanctions can be an effective way of holding leadership accountable and providing the general membership with a level of control and ownership over the cooperative. In Rwanda, bypassing this organic formation of cooperatives has resulted in leadership that are essentially government officials who are not answerable to the members (Huggins, 2014). Portes and Landolt (2000) noted that this can lead to leaders becoming self-serving and result in the failure of the cooperative. The network analysis in this study found that the cooperative networks were highly centred around one or a few members of the leadership, with the President of each cooperative having the most direct connections. These leaders at the centre of the network would have a lot of influence and control over what is communicated about the cooperative to members. Without a more pluralistic leadership structure, it may be challenging to hear alternative perspectives or to hold those at the centre of the networks accountable for their actions. Given that many agricultural cooperatives have been directly created by the state meaning those who lead them often already hold positions of authority (Verhofstadt & Maertens, 2014), the Presidents of these cooperatives are likely to hold a lot of power.

Having powerful and dominating leadership within a cooperative does not necessarily mean the cooperative will fail. If leaders are effective at listening to members, responding to their needs and creating a well-functioning cooperative, social capital is likely to be high as members feel positively towards the group and may feel respected and listened to. This may be what has occurred in the cooperatives in this study. However, if leadership becomes more self-serving and nepotistic it is possible that positive relationships and trust within the cooperative will decrease, especially if there is no effective way to hold leadership accountable due to a lack of social enforcement measures. Therefore, despite high levels of social capital within cooperatives, the sustainability of this social capital and therefore the cooperatives in general may be heavily reliant on the actions of the leadership.

With these factors in mind, the cooperatives cannot definitively be said to be sustainable, as it may depend on how leadership act, or inclusive, as there were marginalised individuals who were not experiencing the same levels of social capital. However, the results of the stepwise multiple regression do show that there was a positive association between social capital and economic empowerment. This means that for those cooperative members who experienced higher levels of social capital, there is evidence to suggest that they were successfully converting this social capital into economic empowerment. For those with lower levels of social capital, economic empowerment tended to be lower. These findings indicate that at least some of the Rwandan cooperatives were using the social capital of members to increase their empowerment.

Dairy 3 had the lowest levels of social capital, although there was a wide range of social capital values within the cooperative. There is no clear evidence as to why social capital in this cooperative was so much lower than the others. As previously mentioned, it could be a reflection of bad leadership creating hostility or tensions within the group. It could also be due to the high proportion of younger members (in the 18-34 group) who are increasingly disinterested in agricultural due to land access issues (Byishimo, et al., 2022) and may therefore be disengaged in the cooperatives they are coerced into joining. It may simply be that the individuals who were brought together in this cooperative did not get on. Without further research, it is not possible to draw a clear conclusion on what has caused the lower levels of social capital, but it does highlight that despite the positive evidence from the other five cooperatives, that the GoR's approach to creating cooperatives might not always be effective.

Both the type of the cooperative and the number of years an individual had been in the cooperative were also determinants of economic empowerment. Members of maize cooperatives tended to have higher levels of economic empowerment when compared to dairy cooperatives. A similar finding was identified by Verhofstadt and Maertens (2014) who found that the effects of cooperative membership on farm performance were driven by the type of cooperative. They found that maize cooperatives increased agricultural intensification, commercialisation and farm income and had a larger effect on farm productivity when compared to horticultural cooperatives. These findings do not align with the common view that cooperatives which focus on higher-value products tend to be more successful (Barham & Chitemi, 2009). It may therefore not be the focus on maize that leads to members having higher economic empowerment but other factors. For example, maize cooperatives have been established for longer in Rwanda and are typically larger than the dairy cooperatives, which may have resulted in better management and leadership.

Another explanation for the higher levels of economic empowerment in Maize cooperatives when compared to Dairy cooperatives could be the milk market structure and dairy policies within Rwanda. It has been a key ambition of the Rwandan government to increase the numbers of cross-bred cows within the dairy sector as they can be more productive than local breeds. However, a failure to introduce supporting policies that focused on good quality feed for cows has resulted in low productivity (Habiyaremye, et al., 2021). The structure of the milk market also favours processors, meaning smallholders are often paid extremely low prices for their milk, with farm-gate milk prices only equating to 16% of the final consumer price, whereas the international standard is 50% (ibid.). This occurs as processers have limited competition so can buy milk from cooperatives at a low price, which is then passed onto the farmers (TechnoServe, 2019). These factors may limit the level of the empowerment farmers feel.

Finally, the number of years an individual has been in the cooperative was also a determinant of economic empowerment. Previous evidence of nepotism in Rwandan cooperatives (Elder, et al., 2012) gives credibility to the idea that longer serving members may be closer to the leadership and receive unfair benefits, furthering their levels of economic empowerment. It could also be that those who have been members of the cooperative for a longer time have greater knowledge of how to maximise their benefit from the cooperatives or may just be more highly respected resulting in their voices being heard more. Again, this is a relationship that needs to be explored further for any clear conclusions to be drawn.

5.6 Conclusion

Overall, this study has found that contrary to previous evidence, social capital does exist and is high in some Rwandan cooperatives. There is evidence to suggest that this social capital increases the effectiveness of the cooperative, resulting in higher levels of economic empowerment for the members. However, doubts about the sustainability and inclusivity of the cooperatives must be considered. The dominant leadership may play a pivotal role in the levels of social capital members experience, and a change in the leadership could have negative consequences if they become more self-serving and dominant. The level of social capital experienced by members also differs within cooperatives. Some individuals have far lower levels, which may be a consequence of them being marginalised from the group. If these individuals are women and youth, as previously identified in other studies, their continued marginalisation may result in unrest and low productivity in the future. Therefore, whilst the GoR ambition to create agricultural cooperatives through policy may have been successful, future research needs to be done on whether they are sustainable.

Chapter 6: Summary and Conclusions

6.1 Summary

This thesis has sought to investigate how social networks can be used to improve Agricultural Innovation Systems (AIS) by examining policies that focus on existing social networks and policies that seek to create new networks.

Chapter 2 of this thesis provided an insight into the current literature on AIS and the role that social networks and social capital can play in increasing their effectiveness. The chapter discussed the key types of failure that occur within AIS and the uncertainties that exist within the system that can form barriers to innovation adoption. Agricultural innovation adoption is generally considered to be low in sub-Saharan Africa (SSA) and with the changing climate exacerbating food insecurity in the region, there is a pressing need for farmers to adopt more sustainable practices (Clay & King, 2019).

Chapter 3 provided an overview of the AIS in Kenya and Ethiopia by focusing on the adoption of forages at the village level. The study highlighted the institutional differences between the countries and how this affected the AIS within them. In Ethiopia, high levels of government intervention meant bridging institutions were dominated by public officials. The agricultural sector operated in a top-down manner, which restricted the ability of farmers to participate in innovation design or have their needs and demands heard. Placing farmers at the centre of the innovation system is considered key to success. In contrast, the government had little involvement in the AIS in Kenya. Instead, farmers relied on each other for forage materials and access to traditional extension officers was far lower when compared to Ethiopia. The study also showed that being market orientated and focused on dairy production led to higher levels of forage planting in Kenya. Whilst there are likely many nuances to these relationships, both of these factors increase the likelihood that dairy farmers were interacting with other dairy farmers and sharing trusted information, which reduce uncertainties and leads to adoption.

In order to explore how policies can effectively use social networks to improve AIS, two existing policy approaches were examined. Chapter 4 builds on the evidence in Chapter 3 that, in Kenya, informal interactions between farmers can be important in innovation adoption decisions. It focused on farmer-to-farmer (F2F) extension, a relatively new approach which has grown in popularity across SSA and that treats farmers as equal partners in the extension process as opposed to students. F2F extension involves a lead farmer being trained by an extension officer who then educates their peers and others in their network on certain innovations. This approach relies on information being passed through a farmer's social network with the view that information is more trusted when it comes from peers. Whilst F2F extension can offer a cost-effective way to reach many farmers, Chapter 4 used social network analysis to demonstrate that how effective the approach is will depend on the network structure. It was therefore suggested that the network structures in F2F extension locations are understood before selecting a lead farmer, and if that is not possible that specific characteristics in terms of market orientation and group membership can be used to help identify individuals who hold important network positions.

Whilst Chapter 3 showed that informal interactions between farmers may affect adoption in Kenya, it also highlighted how the top-down government policies in Ethiopia had failed to establish the significant adoption of forages in the country. Chapter 4 therefore explored a more top-down and government driven approach to using social networks and social capital by examining the effectiveness of agricultural cooperatives that exist as a result of government intervention and policy. Using data from Rwanda, which has many similarities to Ethiopia in terms of government involvement and intervention in the dairy sector, the success of government formed agricultural cooperatives in generating social capital between members was assessed. The results of this study were contrary to many previous studies on Rwanda cooperatives which find that social capital exists in many of the cooperatives and is effectively being converted into economic empowerment for the members via cooperative membership. This therefore offered support for the idea that government policy can be used to create social networks and social capital, which can be turned into tangible benefits for smallholders and will likely lead to an increase in technology adoption. However, doubts over the sustainability of the cooperatives were raised, as much of the social capital being generated may be a result of a well-functioning leadership. Issues surrounding the dominance of leadership and a lack of measures in place to remove leaders may create issues in these cooperatives in the future.

Overall, this thesis has shown how policies that use social networks and social capital can be made more effective given the wider institutional context. Whilst the data and focus of this thesis has been on the dairy sectors of East Africa, the general policy recommendations made in the following section can be widely applied to AIS across SSA as they provide general insight into how AIS can be strengthened.

6.2 Discussion and policy recommendations

The literature review in Chapter 2 of this thesis discussed that AIS can fail due to: infrastructure failures, hard institutional failure, soft institutional failure, strong network failure, weak network failure, capabilities failure and market structure failure. It also explored the effect that uncertainty has in AIS and how this can act as a barrier to adoption. This section of the thesis will discuss how some of the failures and uncertainties that exist in the AIS can be overcome by well-designed policies that focus on social networks and the social capital they generate.

Traditional extension services in SSA have seen mixed success resulting in new approaches to extension, such as F2F extension, emerging (Davis, 2008). F2F extension relies on lead farmers, who are trained by extension agents, to educate and train their peers on new innovations. It is thought that through a process of social learning, other farmers within the lead farmers network will adopt the innovation and it will continue to diffuse through network connections. One of the key advantages of F2F extension is that if the correct lead farmer is selected, they will come with a knowledge of the institutional environment, social norms and cultural context which will allow them to communicate innovations in a manner that is understandable and accepted by others within their network. This may help overcome some aspects of soft institutional failure. However, to ensure this, the individual selected to be the lead farmer must have knowledge of these social norms and be respected and accepted within the community. Individuals who have the most connections in a social network are generally trusted and respected, which would make them ideal lead farmers (Cassidy & Barnes, 2012). Chapter 4 demonstrated that social network analysis can be used to identify individuals with the most connections and therefore there are benefits to mapping out farmer networks in F2F extension locations. In circumstances where mapping out networks is not possible, Chapter 4 found that the individuals who had the most connections to others in the network tended to be male, be a member of groups such as cooperatives or informal finance collectives and be more market orientated. Using these characteristics may help F2F extension projects target farmers who are influential and respected. However, despite the benefits that can arise from selecting well-connected individuals to be lead farmers, consideration must also be given to ensure marginalised groups, such as women, are not excluded from F2F extension services. These individuals tend to have fewer connections and therefore information may not reach them easily.

Some of the uncertainties smallholders in AIS experience can be overcome if they believe the information they are receiving comes from a trusted source. Distrust of extension officers is common in SSA and can result in farmers becoming disinterested and disengaged in the information and training they receive (Spielman, et al., 2010) . However, being supplied inputs and information from a trusted farmer increases its credibility. Lead farmers are also often encouraged to produce demonstration plots, which reduces uncertainties regarding the technology as farmers are able to get a better perspective of how the technology fits with the current infrastructure and of how the technology itself works and the risks associated with its use. If the lead farmer is well respected in their community, this may also minimise levels of social uncertainty and farmers will be more open to adopting.

Soft and hard network failures occur when either networks are too tightly bonded for external information to enter into the network or when actors are too weakly connected that no meaningful collaboration occurs between them. It is therefore important that information on innovations is passed from research institutes to farmers via individuals who have strong connections with others in the networks. Chapter 4 showed that the network structures of dairy farmers in Kenya differ. Some of the networks showed that individuals held key bridging positions where they linked different parts of the network together. Focusing on these individuals as lead farmers can help reduce soft network failures as the farmer already has meaningful connections with different farmer groups and can facilitate effective communication between heterogenous groups of farmers and potentially other actors in the AIS. Chapter 4 found that individuals in bridging positions tended to sell produce at markets, which offer an important venue for information transfer, as supported by the findings in Chapter 3. In more tightly bonded groups, there may be no individuals who hold bridging positions, which is how hard network failure occurs. In these networks, the well-connected individuals will have high levels of influence and can change the perceptions and actions of others in the network. If these individuals are trained as lead farmers, this can help overcome hard network failures by creating important bridging links to other actors in AIS.

This thesis therefore offers support for the idea that correctly designed F2F extension strategies offer an opportunity for several uncertainties and failures that exist within AIS to be overcome. This would result in higher levels of innovation adoption and agricultural development. However, for such policies to be their most effective, this thesis argues that attention needs to be given to selecting lead farmers who are well positioned within their networks. If lead farmers are chosen who are not respected and trusted, there is chance for failures and uncertainties to be further exacerbated and for smallholders become more disinterested in extension activities.

It is widely regarded in the literature that for AIS to be successful, they need to be pluralistic and treat farmers as co-partners in the innovation process (Hall, 2007). However, this approach to agricultural innovation is at odds with many government policies and procedures. Some governments maintain tight control over their agricultural sectors with top-down policies and an AIS dominated by public actors, such as in Ethiopia as shown in Chapter 3. A common element in such approaches to agricultural development is the introduction of agricultural cooperatives as a vehicle for development. These agricultural cooperatives rely on social networks and social capital to successfully operate and can act as important bridging organisations within AIS connecting smallholders to other actors such as buyers, research organisations and input providers to share knowledge and information.

Chapter 5 argued that contrary to previous evidence on the topic, in Rwanda the agricultural cooperatives that have been developed as a result of government intervention have been effective in generating social capital which has increased smallholder’s economic empowerment. Membership to cooperatives can help farmers overcome market failures and market uncertainty as they are guaranteed to sell their milk to the cooperative and can demand higher prices for it due to their group bargaining power. However, Chapter 5 argued that in Rwanda, bad government policies that favoured dairy processors as opposed to the producers had reduced the level of empowerment and benefits farmer experienced (TechnoServe, 2019). This is an example of hard institutional failure. The ability of cooperatives to overcome market failures in AIS is therefore also dependent on wider policies which should favour smallholders as they disproportionately experience the negative effects of market failure.

Agricultural cooperatives can help overcome resource and institutional failure by offering smallholders access to finance and loans. These loans are usually paid for using membership fees and cooperative profit and therefore rely on commitment from smallholders to the cooperative. However, commitment from smallholders is underpinned by social capital between cooperative members as they need to trust the other members and be willing to act in the interests of the whole group, similar to the other forms of collective action. Chapter 5 argues that in Rwanda, the level of social capital in agricultural cooperatives may be heavily dependent on the leadership, as if the cooperative is being run well members are likely to feel positively towards it and the other members. However, a lack of social enforcement mechanisms and high levels of government intervention in the cooperative means that if the leadership starts acting in their own interests, the general membership may be unable to remove them, resulting in more distrust and discontentment within the cooperative.

In a similar vein, cooperatives can offer training and inputs to their membership which reduces capability failures and reduces uncertainties regarding various innovations. However, in countries such as Rwanda and Ethiopia where the government has control over research organisations and many other aspects of the agricultural system, the training and inputs farmers receive may not meet farmer demands or needs and therefore be unhelpful. This was highlighted in evidence given in Chapter 5 where the Rwandan government provided farmers with cross-bred cows to increase productivity, yet farmers did not have the training and resources to feed the cows and therefore few productivity gains were observed (Habiyaremye, et al., 2021). The success of cooperatives in meeting the needs of the membership and therefore overcoming capability failures and uncertainty is reliant on leadership being able to communicate to higher levels of authority the needs and issues their members face. Again, in government created cooperatives, there is more potential for leadership to become self-serving and therefore not act in members interests reducing the effect that cooperatives can have in overcoming AIS failures.

Overall, cooperatives created through government policies can produce social capital and therefore overcome some of the failures and uncertainties that hinder agricultural innovation adoption. However, the extent to which these cooperatives can support AIS depends on the wider institutional context and on how they are managed and run. If they fail to respond to members needs and leaders become self-serving, less social capital will be occur between members and many of the potential benefits will be muted. When creating cooperatives, this thesis finds that it is important to include processes that allow leadership to be held accountable for their actions and for consideration to be given to the wider policy environment.

This thesis therefore proposes the following recommendations:

- **Policy makers should develop an understanding of individual AIS their weaknesses and design policies which address this.** Due to different institutional contexts and social norms, the failures and uncertainties experienced in one AIS will be different when compared to another. When designing policies that seek to make AIS more effective, it is important to first know the weaknesses.
- **Identifying the right 'gatekeepers' to farmers networks is vital to overcoming AIS uncertainties and failures.** Whether these gatekeepers are cooperative leaders, lead farmers or another access point into farmer networks, ensuring they are well positioned or well respected within a network will have significant impacts on the success of any policies.
- **Policies that use social networks and social capital to improve AIS are only one piece of the puzzle.** The wider political environment and policy approaches also need to support these policies.

6.3 Limitations and further work

The key limitation to this thesis is its focus on East African dairy systems. The study chapters in this thesis offer in-depth insight into East Africa and provide many context specific conclusions and recommendations. Whilst Chapter 6 brings together the results of these studies and proposes some generic policy recommendations that can be applied outside of the East African dairy context, these recommendations are limited by what can be concluded from such context specific results. Further studies focused on different AIS and different agricultural sectors would positively add to this body of literature.

A recurring theme that occurred in the study chapters of this thesis was the important of the enabling environment and institutional context on the success of social network focused policies. It was outside the scope of this thesis to fully develop an understanding of the co-dependencies of various innovation policies however this will undoubtedly affect the success of the policy recommendations. This is therefore a key area for future research.