The Roles of Absorptive Capacity, Technology Adoption, and Extension Services in a Local Agricultural Innovation System in Sri Lanka

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Abstract

Sustainable agriculture development is realized through the local Agriculture Innovation System(AIS) of the country. Actors of the agriculture innovation system interacting with each other in technology generation, processing, dissemination, and utilization process to sustain the progress of the development process. AIS of the developing countries are in a disadvantageous position in generating and learning innovation. This study analyses the contributions of the individual elements to the performances of the AIS in context to Sri Lanka. First, the study analyzes the determinants of R&D institutes' innovative and knowledge sharing performance. Secondly, the study analyses the ACAP of individual extension officers and determinants impacting their performances. Finally, farmers' knowledge sharing process and technology adoption behaviors are analyzed. Therefore, this study consists of five related but independent studies based on local AIS in Sri Lanka.

First, the study reveals that the ACAP of R&D institutes is primarily shaped by system and coordination capabilities, and to a lesser extent by socialization capabilities. Furthermore, coordination capabilities impact to a greater degree for organizations' potentia*l* ACAP and system capabilities for realized ACAP. The empirical results based on network perspectives show that institutes with higher organizational ACAP and scientific publications hold more prominent network positions. Further, those institutes more frequently acquire external knowledge from publications and professional conferences empowering to achieve higher levels of innovation performance. The second study focuses on the Agricultural extension services and diffusion of knowledge and examines the extent to which AIs' capabilities to identify, assimilate, utilize, and share knowledge are shaped by their motivations, abilities, and opportunities (MOA). The study Interviews 72 AIs in the Southern province of Sri Lanka. The empirical findings show that AIs' abilities and opportunities contribute to the development of four dimensions of individual ACAP. In contrast, motivation does not seem to be of relevance in this context. Finally, this study explores the access and use of agricultural knowledge and information by paddy farmers in the Hambantota district in Sri Lanka. The study found that formal information-sharing processes are dominant among paddy farmers and farmers receive and share information more frequently and formally with the AIs. AIs are perceived as the most trusted and most accessible information sources by the farmers. Further, the farmer's age and farming experience show a positive relationship with the adoption of new technologies, while technology adoption behavior is not significantly affected by the social and demographic factors of farming communities. Furthermore, the empirical results show that only 40 to 60 percent of farmers are actually inclined to adopt new agricultural technologies. Technological constraints are shown to be the most dominant adoption barriers for paddy farmers. Therefore, this study recommends to overcome technological barriers to upgrade adoption of agricultural technologies.

Finally, this study recommended to initiate more collaborative activities to enhance the knowledge generation and diffusion in AIS in Sri Lanka. Moreover, the formal knowledge sharing process through AIs is recommended to enhance the productivity of the extension service in Sri Lanka. At last, private-public partnerships in research and extension services are recommended to uplifting the efficiency of the agricultural innovation system in Sri Lanka.

Keywords: *Absorptive capacity, Agriculture innovation system, Extension service, Farmers adoption, technology adoption*.

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List of Abbreviation

R&D - Research and Development

GDP - Gross Domestic Production

DOA - Department of Agriculture

FFS - Farmer Field School

AI - Agriculture Instructor

DAEO - District Agricultural Extension Officers

KVS - *Krushikarma Viyapthi Sewaka*

T&V - Training and Visit System

SAEP - Second Agriculture Extension Project

ACAP - Absorptive Capacity

PACAP - Potential Absorptive Capacity

RACAP - Realized Absorptive Capacity

MOA - Motivation-Opportunities-Abilities

OLS - Ordinary Least Square

RRI - Rubber Research Institute

TRI - Tea Research Institute

VRI - Veterinary Research Institute

IRRI - Rice Research Institute

CRI - Coconut Research Institute

IPHT - Institutes of Post-Harvest Technology

NRMC - Natural Resource Management Center

NARA - National Aquatic Resources Research and Development Agency

AO - Agriculture Research Officers

DS - Divisional Secretariat

GN - *Grama Niladari* Divisions

PGIA - Postgraduate Institute of Agriculture

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Chapter 1

Introduction

1.1 Background of the thesis

Agriculture serves as the main source of income for the majority of the rural population in developing countries. Accordingly, a steady increase in agricultural productivity is still a necessity to raise their economic growth. However, recent cases of food scarcity and spikes in food prices have intensified the need for higher productivity within the agricultural sector (Lotze-Campen et al., 2008; Ballantyne, 2009). At the same time, it is important to ensure that this growth will be realised through sustainable practices (Tscharntke et al., 2012). As in other sectors, this can be achieved through innovation and research and development (R&D), as novel and up-to-date agricultural knowledge and information are essential to increase production, productivity and marketing (Dibaba, 2018). Consequently, the progress depends on (further) developing local agriculture innovation systems including the interactions between those involved in technology generation, processing, dissemination and utilisation (Dibaba, 2018).

A great deal of research has been produced on (local) innovation systems (Spilman, 2005; Agwu et al., 2008; Andrew Hall et al., 2000; Andy Hall, 2003; Klerkx et al., 2010; Hall et al., 2003; Hall, 2007: Klerkx et al., 2012; Assefa et al., 2012; Brooks & Loevinsohn, 2011; Koutsouris, 2012), but less attention has been paid to local innovation systems in developing countries. However, it is well-known that insights on innovation systems from developed countries cannot easily be transferred to developing countries. The latter countries are confronted with significant

institutional challenges, including insufficient funding for agricultural R&D (Pardey & Beintema, 2001). The insufficient funding of agricultural R&D represents a major challenge, although these countries spend considerable sums on agricultural research relative to their national budget. Consequently, they find themselves in a disadvantageous position in generating and learning about innovation.

This situation is further exacerbated as, in contrast to other research fields, it is usually necessary to adapt agriculture-related technologies to local conditions, which is a main driver behind almost all agriculture research (Pardey & Beintema, 2001). In this context, the implication is that innovation and new technologies that might be globally available still require substantial R&D efforts to become applicable in a specific country.

Adding to this, the majority of farmers living in rural areas of developing countries are constrained in their ability to access up-to-date technologies and new knowledge (Lwoga et al., 2011; Buah et al., 2011). In this context, the weak institutional system of a developing country prevents potentially available technologies from advancing from global availability to actual implementation. Consequently, developing countries are also disadvantaged in the adoption and utilisation of new technologies (Aseno et al., 2008).

These issues have partly been recognised by policy makers, who have developed remedial measures in an attempt to address concerns. Traditionally, those who create policy have focused on improving R&D and upgrading education programmes in this context. In addition, the diffusion of knowledge within the economy and in particular from the public research sphere to the private sector is increasingly seen as a viable policy target (Bednarz & Broekel, 2019). However, public policy and public research in developing countries focuses on a wide range of R&D topics and, additionally, has limited capacity to fulfil the overall R&D demand and that for agricultural R&D in particular (Mukherjee & Maity, 2015; Swanson & Samy, 2002). Private research investments remain low in developing countries and hence are insufficient to compensate for the lack of public research (Mukherjee & Maity, 2015). Nevertheless, public-private partnerships are seen as a promising possibility to overcome this deficit (Swanson & Samy, 2002).

Similarly, public extension services play a vital role in the agricultural innovation systems in developing countries (Pardey & Beintema, 2001; Swanson & Samy, 2002). While research institutes generate new knowledge, agricultural extension services are frequently responsible for its dissemination to farmers. In many developing countries, the agricultural extension service is the central node through which to establish interactions that connect the public and private research spheres with farmers (Sulaiman & Hall, 2002). In addition to being active disseminators of useful knowledge, extension services are also crucial in establishing mechanisms that bring together other actors within the innovation system.

While these extension services are one focus of the current thesis, concentrating on just one of the many elements of agricultural innovation systems is insufficient. To fully understand the performance of local innovation systems, this thesis will also consider the research sphere, which generates new knowledge and offers access to new technologies. Attention will also be paid to the end users (farmers), who similarly contribute to the performance of the system. Moreover, the thesis acknowledges that the contributions of individual actors to the performance of the innovation system are conditional on their interactions as a group (e.g. to function properly, the innovation system requires effective coordination and collaboration between its individual elements).

This study concentrates on Sri Lanka as one example of a developing country that is highly dependent on the agricultural sector. While during the 1970s Sri Lanka's economy was predominantly agriculture based, it has recently shifted towards a service- and manufacturing-oriented economy. In 2018, agriculture contributed 7% of the national GDP, with the manufacturing and service sector accounting for more than 80% (Central Bank of Sri Lanka, 2018). Nevertheless, while the manufacturing and service sectors are more important in terms of contribution to GDP, the relative significance of the agricultural sector has not substantially diminished. It still forms a major component of the national economy and represents the primary means of rural livelihoods. This is highlighted by a review of the relevant statistics. In 2018, for example, the agricultural sector accounted for 31% of the total workforce nationwide. Further, about 1.8 million families are engaged in farming activities in Sri Lanka. Most of them are small-

scale farmers, and 64% cultivate less than 0.8 hectares of land (Department of Agriculture, Sri Lanka, 2018). The agricultural sector also plays a significant role in the country's exports. For instance, tea is considered one of the most prominent exports (in terms of value) of Sri Lanka (World Bank, 2019).

Adding to the importance of the agricultural sector is its extensive forward and backward linkages to the manufacturing and service sectors. This particularly applies to the food and food-processing industries (Girihagama et al., 2012). Therefore, the agricultural sector represents an important source of growth for the country's economy, which requires constant upgrading and development through innovation and the adoption of new technologies, i.e. a well-functioning agricultural innovation system (Dasanayaka, 2003).

This is also recognised by policy. Adequate planning and coordination, collaboration and synchronisation of research, extension services, and knowledge diffusion have been a focus in Sri Lankan policies during the last few decades. For instance, the Department of Agriculture of Sri Lanka initiated and fostered the use of on-farm training and demonstration, Farmer Field Schools (FFS), field days, and field visits. In other words, the department aimed at promoting links between research, mediating services, and farmers. These initiatives seem to have had some success, as the frequency of interactions between the different stakeholders has grown in recent years (Dibaba, 2018).

1.2 The agricultural innovation system of Sri Lanka

As in many other developing countries, Sri Lankan agricultural extension services started in the post-independence period. Previously, the focus was primarily on the development of the plantation sector. At the time of independence, there were almost no extension services directed toward local farmers (Wijerathna & Silva, 2004). For instance, in 1880 only four agricultural instructors (AIs) were appointed to serve the entire country. In 1923, the country was divided into three divisions and the Divisional Agricultural Office was founded, assisted by few AIs. They

were expected to fulfil all duties of the extension service, including providing advice, research, managing government farms, and offering veterinary services (Wijerathna, 1988).

In the post- independence period (after 1948), the Sri Lankan agricultural extension services engaged in the renovation and reconstruction of the irrigation system. The low productivity of farmers at the time had to do with the cultivation of traditional rice varieties. To stimulate growth, the government supported the introduction of higher yield strains of rice. This required an effective system of communication between public agricultural authorities and farmers (Wijerathna & Nilantha, 2004). The system was further improved with two major significant transformations after 1957. The first transformation was the replacement of district agricultural officers with agricultural extension officers. Secondly, for the first time the extension services began to consider the local level. More precisely, village-level extension officers were appointed, known as *Krushikarma Viyapthi Sewaka*. These changes were seen as a major reform of the agricultural extension services.

The system was further altered when extension activities became more demanding and intensive. In 1963, a separate extension division was established in the Department of Agriculture. In the 1970s, another set of reforms was implemented to further raise the effectiveness of the extension services. The Training and Visit System of agricultural extension was created in 1978. In 1990, the system was further decentralised and, in 1993, the Second Agricultural Extension Project (SAEP) was instituted. SAEP was designed to integrate extension activities across key components of the agricultural sector such as food crops, livestock, export crops, and coconuts. This made the extension system more participatory but it had limited success, mainly due to lack of cooperation between working departments (World Bank, 2007). Since then, the system has experienced few reforms. Even though the Sri Lankan extension service underwent a series of reforms, it is still far from offering high-quality extension services across the country (Wijerathna & De Silva, 1998).

Mirroring the development of the extension services, the innovation system of Sri Lanka is inferior to that of more developed countries. For instance, interactions between research institutions, intermediaries, and technology users are limited to field activities, training sessions,

regular meetings, demonstrations, and occasional events such as conferences, symposiums, and exhibitions. Moreover, these interactions are constrained by time, space, and the objectives of the actors involved in the process. This is seen as a major deficiency of the extension services (Jayathilake et al., 2006). Nevertheless, in some regions the vast majority of farmers heavily rely on public extension officers (Silva & Broekel, 2019) and interactions between farmers, farming organisations, and market venders do occur at considerable levels of intensity (Jayathilake et al., 2006, 2015).

In sum, the extension service system is still challenged to ensure the diffusion of useful technologies and information to farmers (Jayathilake et al., 2015; Dasanayake, 2003). This situation provides the background for the current thesis.

1.3 The elements of the innovation system in focus

The first element of the innovation system under review in the present thesis is agricultural R&D institutes, which in Sri Lanka are almost all non-profit service organisations. This contrasts with the focus of contemporary research, which primarily investigates private and profit-oriented innovation activities in developing countries (Tsia, 2002; Kim, 1998; Fosfuri & Tribo, 2005; Cohen & Levinthal, 1990). Instead, this thesis concentrates on how these research organisations differ in terms of their capacities to access, absorb, and utilise external knowledge as well as how this relates to their performance. A number of existing studies analyse how organisational absorptive capacity (ACAP) affects innovative performance in developing countries (van den Bosch, 1999; Jensen et al., 2005; Zahra & George, 2002). However, while it is well established that universities provide access to global pipelines of knowledge and are also able to adapt technologies to local contexts in developing countries (Dalrymple, 1999; Beintema & Stads, 2010), much less attention has been paid to other types of research organisations or with respect to agricultural public research in particular (Dalrymple, 1999). Similar criticisms apply to the private sector, which is also a recognisable source for technologies in this context (Pardey & Beintema, 2001). However, in contrast to publicly-funded research organisations, the private research sector serves a small

subset of farmers' needs. Notwithstanding, private R&D still shows substantially higher returns on investment (David et al., 2000).

The second element of the innovation system studied by this thesis is the extension officers, who link (public) research organisations to the end users of knowledge and technologies, namely farmers. More precisely, these services obtain knowledge from research institutes and strive to strengthen the bond between these institutes and farmers (Faure et al., 2012). These services are particularly relevant in developing countries, as farmers have poor access to knowledge and information. Extension officers play a role as 'technological gatekeepers', absorbing external knowledge and sharing information with farmers. These services have received relatively little attention in the literature to date (Agwu et al., 2008; Eicher, 2007; Tandi, Lwoga et al., 2011; Buah et al., 2011; Sulaiman & Hall, 2002).

The third element of the agricultural innovation system that the present thesis concentrates on is farmers. Farmers' adoption of agricultural technologies is the ultimate purpose of an innovation system. As pointed out above, the other two elements (research institutes and extension services) are essential for the diffusion of knowledge. However, farmers differ in individual characteristics and their embeddedness in the innovation system leads to heterogeneity in their adoption of technologies. These differences have been rarely investigated, which motivates this aspect of the thesis (Adebiyi & Okunlola, 2013; Doss, 2003; Lev & Acker, 1994; Maffioli et al., 2013).

As the fourth element of the innovation system, this project explores the structure and nature of networks among farmers. Through these networks, farmers share a wide range of information, including knowledge on cultivation approaches, market conditions, and subsidies. This thesis complements existing research in this context by shedding more light on social networking and peer effects in individual technology adoption within the context of agriculture and developing countries (Bandiera & Rasul, 2006; Conley & Udry, 2010; Llewellyn, 2006; Conley & Christopher, 2001).

It is beyond the scope of the thesis to study these elements for the entire agricultural innovation system of Sri Lanka. Rather the thesis focuses on the agricultural innovation system in the

Hambantota district, one of the major agricultural provinces in the country. Following the rich literature on regional innovation systems (see Cooke et al., 1997), this study applies an explicit regional perspective. This allows for a more fine-grained and hence more precise analysis. Accordingly, using this district as an example, the thesis will address questions such as: What factors influence the performance of stakeholders such as research organisations and extension services? What role do the characteristics of (research) organisations and individuals (e.g. extension officers) play in this context? Due to its geographical focus, the answers to these questions will remain limited in their generalisability and transferability to the situation in Sri Lanka. As a side effect of the domination of paddy cultivation in the district, the thesis will moreover deliver insights into the paddy sector, paddy development technologies, and agricultural extension services related to this technology.

1.4 Theoretical basis of the study

This investigation employs a knowledge generation and diffusion perspective, whereby the concepts of absorptive capacity (ACAP) (Cohen & Levinthal, 1990) and knowledge diffusion (Rogers, 1995) in particular take centre stage. Originally, ACAP was defined as 'a firm's ability to identify, assimilate, and exploit knowledge from the environment' (Cohen & Levinthal, 1989, 21). Later, Zahra and George described ACAP as 'a set of organisational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge' (2002, 186). Subsequent studies have suggested different multi-dimensional definitions of this concept, two of which have become prominent at the organisational level. The first dimension is *potential* ACAP, which includes the processes by which an organisation can absorb external knowledge from the environment. The second dimension is *realised* ACAP, which refers to the processes by which the absorbed external knowledge can be used for a specific purpose within organisations (Zahra & George, 2002). Hence, *potential* ACAP includes the capability to acquire and assimilate external knowledge, though that does not guarantee its application. In contrast, *realised* ACAP implies the competence to transform and exploit absorbed knowledge.

Crucially for this thesis, ACAP has been translated to the individual level. Individual-level ACAP is also composed of *potential* and *realised* ACAP (Da Silva & Davis, 2011). It includes individuals' capabilities to acquire and assimilate external knowledge, which collectively creates an organisation's ACAP. In this thesis, all of these concepts will be applied to and utilised for the analysis of agricultural extension officers and their services.

Moreover, the thesis uses extension services as a case study to analyse the individual dimension of absorptive capacity, which, so far, is primarily studied at the organisational level. Building on the work of Ter Wal et al. (2011), the ACAP of extension officers' is assessed by looking at their abilities to identify, assimilate, utilise, and transform external knowledge. Notably, the thesis extends this research to the context of the non-profit sphere, where it will be argued that personal abilities, motivation, and socialisation mechanisms are of crucial importance for the success of these officers.

In addition to the concept of absorptive capacity, the thesis heavily draws on the literature on knowledge diffusion, as this is a central element of the agriculture innovation system (Mekonnen et al., 2016). There is an extensive body of work on the diffusion of innovations and its determinants (Hägerstand, 1967; Rogers, 1995; Abdulai & Huffman, 2005; Adebiyi & Okunlola, 2013; Adesina & Baidu-Forsen, 1995; Agbamu, 1993; Akudugu et al., 2012; Anne-Marie & Brush, 1992; Atibioke, 2012; Bandiera & Rasul, 2006; Conley & Udry, 2010). One of the classic takes on technology diffusion is Rogers's (1983, 1995) 'diffusion of innovations' theory. He defines diffusion as 'the process by which an innovation is communicated through certain channels over time among the members of a social system' (Rogers, 1983, 5). In addition, he suggests five stages in the diffusion of technologies (or products): (1) knowledge (awareness and basic understanding); (2) persuasion (the process of forming an attitude toward the innovation); (3) decision (activities leading to a choice to either adopt or reject); (4) implementation (putting the innovation into practice); and (5) confirmation (seeking reinforcement for continued use). The existence and relevance of these stages has been confirmed in the literature (Sahin & Rogers, 2006; Fichman, 1992; Rogers, 2010). Moreover, it has stimulated the discussion of different strategies when actively seeking to distribute technologies (Backer, 1991; Adesina & Baidu-

Forsen, 1995; Agbamu, 1993; Akudugu et al., 2012). This provides a valuable theoretical backbone to the present thesis.

In sum, the thesis provides deep insights into the agricultural innovation system in the Hambantota district of Sri Lanka. It sheds light on a wide range of aspects of the system including the determinants of R&D institutes' innovative and knowledge sharing performance; the state of the knowledge network among agricultural R&D institutes; the ACAP of individual extension officers; officers' concerns and constraints impacting their performance; and farmers' knowledge sharing, technology adoption, and success. To do so, the thesis outlines five related but independent studies. The summary of each chapter is outlined below.

Chapter 2: The impact of system, coordination, and socialisation capabilities on the absorptive capacity of non-profit research organisations in developing countries

The application of the ACAP concept in various fields and levels of analyses has resulted in a range of studies focusing on the identification of reasons for its variation (Abreu et al., 2006; Fosfuri & Tribó, 2008; Jansen et al., 2005; Lenox & King, 2004; van den Bosch et al., 1999; Vega-Jurado et al., 2008; Abreu et al., 2012; Tsai, 2001). Despite growing research interest, the identification of the determinants of ACAP as well as the quantification of its importance for organisations' performance (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Giuliani & Bell, 2004) rarely have been explored in relation to non-profit organisations (van den Bosch et al., 1999; Lane et al., 2001; Zahra & George, 2002; Jensen et al., 2005). This motivates the first chapter of the thesis.

Chapter two focuses on the role of ACAP in public non-profit R&D organisations. More precisely, it seeks to explore how different organisational antecedents matter for the *potential* absorptive capacity (PACAP) and the *realised* absorptive capacity (RACAP) of these organisations. In this context, the study pays attention to organisational characteristics and capabilities that impact these organisations' competencies in knowledge acquisition, assimilation, transformation, and exploitation. Moreover, it differentiates between three types of capabilities: system, coordination, and socialisation capabilities. The first represents the direction, policies,

procedures, and manuals that are used to integrate explicit knowledge. According to Galunic and Rodan (1998), system capabilities reflect the degree to which rules, procedures, instructions, and communication are laid down in a formal system. The second refers to capabilities that shape knowledge absorption by means of knowledge and informational linkages between individual members of an organisation (van den Bosch et al., 1999). The third captures firms' abilities to produce a brief ideology that offers members an attractive identity as well as a collective interpretation of reality (van den Bosch et al., 1999). Thereby, the study provides a better understanding of why some organisations are able to acquire and assimilate new knowledge from external sources, and why others may fail in transforming and exploiting it effectively.

The study relies on primary data collection from a sample of 29 agricultural R&D institutes. It reveals that R&D institutes in Sri Lanka have restructured and reformed their organisational structures as well as internal communications systems to enhance their ACAP. They also have allocated more research funds and provided training for staff to upgrade their abilities to generate and diffuse new information. Moreover, the findings indicate that the organisational mechanism associated with system and coordination capabilities is correlated to an organisation's ACAP. For instance, the creation of formal rules, as an expression of system capabilities, helps organisations build *realised* ACAP. This finding is interesting as it contrasts the negative relationship between the two aspects (ACAP and system capabilities) argued by Jansen et al. (2000). Accordingly, this issue remains an interesting area for future research. Coordination capability clearly adds to the development of *potential* ACAP. In this context, the study confirms the argument of Cohen and Levinthal (1990) that participation is a crucial mechanism to connect with the external environment. With respect to socialisation practices, the study does not identify any effects on organisational ACAP, which contrast with the results of Jansen et al. (2005).

In sum, the second chapter of the thesis underlines the importance of differences between *potential* and *realised* ACAP, as they are related to distinct organisational capabilities and are shaped by specific mechanisms. In addition, the chapter identifies factors responsible for the heterogeneity among agricultural research institutes in Sri Lanka in terms of their abilities to

acquire, assimilate, transform, and exploit new knowledge. Put differently, it highlights the heterogeneity of this element within the innovation system.

Chapter 3: The knowledge network of agricultural R&D institutes in Sri Lanka: The relevance of network position and ACAP for innovative performances

In a knowledge-based economy, external expertise is a key ingredient for organisational innovation (Kostopoulos et al., 2010; Morgan & Berthon, 2008; Cassiman & Veugelers, 2006; Boschma & Ter Wal, 2007; Cohen & Levinthal, 1990). However, many organisations are not successful in acquiring and utilising external knowledge and, hence, they experience difficulties in creating knowledge and achieving a competitive advantage (Cassiman & Veugelers, 2006; Escribano et al., 2009). Many of these organisations are small, young firms, or are located in more peripheral regions.

The existing literature has focused on the relationship between local knowledge networks and the innovation performance of firms in developed countries (Powell et al., 1999; Broekel & Boschma, 2012) or within industry-specific clusters (Ter Wal & Boschma, 2007). The literature on gatekeeper organisations is similarly well developed (Giuliani, 2002; Morrison, 2008; Graf, 2012). In developed countries, gatekeeper organisations – typically large firms or universities – frequently help in overcoming these difficulties, as they make external knowledge more easily available by diffusing it into the local knowledge base, upon which, in turn, disadvantaged firms rely (Giuliani, 2002; Graf, 2012).

However, the situation is different in developing countries. Here, gatekeeper organisations are mostly public R&D institutes, as large firms and universities are rare. Consequently, it is unclear what insights from studies based on developed countries can be transferred to developing ones. In addition, most of this literature relating knowledge sourcing and sharing to innovation performance has focused on profit-oriented organisations. In particular, the roles of non-profit (and often publicly funded) R&D organisations in creating new innovations in developing countries has been poorly investigated. The present paper seeks to fill this gap by studying the knowledge sourcing of agricultural R&D institutes in Sri Lanka. The analysis relies on both primary

and secondary data from 29 agricultural R&D institutes in Sri Lanka. Primary data were collected by interviewing the head figures of the research institutes. Internal records and annual reports are used as secondary data to illuminate innovation performance in terms of the number of publications and patents, R&D contracts, and R&D collaboration activities.

At its core, this study follows Giuliani and Bell (2005) and analyses the relationship between knowledge transfer activities and these institutes' innovation performances. The investigation confirms the distinct roles research institutes play in the inter-institute knowledge network. For instance, some R&D institutes act as 'net sources' who share knowledge with other research institutes rather than exploiting specific knowledge. Moreover, this study identifies the Postgraduate Institute of Agriculture (PGIA) as the primary knowledge hub of the network.

Using a multivariate regression approach, the study finds that higher levels of network embeddedness seem to support the institutes in creating (basic) research outcomes. Crucially, this depends on their ability to utilise the knowledge diffusion of the network. Interestingly, the empirical results suggest the existence of a network failure: institutes with relatively small ACAP are named more frequently as important knowledge sources than institutes with higher levels of ACAP. The study thereby hints at the existence of substantial information asymmetries in the innovation system, which calls for policy intervention.

Chapter 4: The effect of the motivation-ability-opportunity (MAO) framework on the ACAP of individual AIs

Originally ACAP was identified as an organisational determinant that represents 'a firm's ability to identify, assimilate, transform and exploit external knowledge' (Cohen & Levinthal, 1989, 21). In this chapter, the concept of ACAP is transferred from the organisational to the individual level to study the performance of agricultural extension service officers. While prior studies have considered ACAP at the individual level (Minbaeva et al., 2007; Da Silva & Davis, 2011; Sikkens, 2013; Yildiz et al., 2019), none have yet addressed the working of a crucial element of the innovation system in a developing country. More precisely, this study focuses on individual

behaviours as expressed in the four dimensions of ACAP. For each of these dimensions, it seeks to identify individual-level determinants. To accomplish this, the motivation-opportunities-ability (MOA) framework is adopted and used to identify factors contributing to the development of individual-level ACAP (Bresman et al., 1999; Minbaeva et al., 2003).

Individual motivation has been defined by Yildiz et al. (2019) as the level of an individual's willingness to augment their skills in recognising, assimilating, and exploiting new external knowledge. This study differentiates between extrinsic and intrinsic motivations, and the ability of individuals is defined through human attributes such as prior achievements, skills, attitudes, and experiences that enable the individual to acquire new knowledge (Yildiz et al., 2019; Bos-Nehles, 2013; Argote et al., 2003). Opportunity is understood as environmental and contextual elements that enable knowledge creation, retention, and absorption actions (Siemsen et al., 2008). Opportunities are empirically measured in terms of individuals' work environments and how their daily work context is shaped by socialisation practices.

For the empirical analysis, the study focuses on a large group of agricultural instructors (AIs) working in the Southern province of Sri Lanka, which is the one of the most prominent agricultural regions of the country. Data is collected by means of a structured questionnaire. The empirical findings of the study confirm an individual's ability to be positively associated with the development of individual ACAP in terms of knowledge assimilation and utilisation. Similar results are found for opportunities that have a significant impact on knowledge identification, assimilation, and transformation. In contrast, no relationship was found between an individual's motivation and their development of ACAP.

On this basis the chapter provides a number of policy recommendations, which include how extension services can prepare and encourage their officers to absorb and transfer new knowledge. In particular, the development of communication skills, team building, and the creation of a corporate culture stimulating knowledge sharing are most likely to be effective in this context.

Chapter 5: Accessing and using agricultural information and technology – Evidence from paddy farmers in the Hambantota district of Sri Lanka

Among agricultural practices, farming can be considered particularly knowledge-intensive. Farmers require knowledge and information as to the technical aspects of farming, climatic conditions, marketing and financial data, and managerial skills to make their farms profitable (Foster & Rosenzweig, 1995; Munshi, 2004; Bandiera & Rasul, 2002). These demands have increased further in recent years due to the advancement of new technologies (Udry, 2010). Fittingly, Pipy Fawole (2008) confirms the positive relationship between an increased flow of this type of knowledge and agricultural development. Generally, farmers acquire information from multiple sources including extension agents and social media (Foster & Rosenzweig, 1995: Munshi, 2004; Bandiera & Rasul, 2002; Conley & Udry, 2010; Krishnan & Patnam, 2012). However, farmers also obtain and share information and knowledge through local social networks, i.e. via interactions with their neighbours (Bandiera & Rasul, 2002).

The majority of the research conducted to date has focused on (informal) relations among farmers and other contacts without much differentiation between sources or quality (Bandiera & Rasul, 2006; Magnan et al., 2015). The study in this chapter extends the literature by considering formal channels of information flow and by adding a qualitative dimension to knowledge sharing. To be more precise, the study differentiates and contrasts the most *prolific* and the most *useful* information sources, something that has rarely been considered in the existing literature. In addition, this project highlights the heterogeneity of farmers in terms of adoption behaviour. Its empirical analysis concentrates on information flows and knowledge sharing patterns among paddy farmers in the Hambantota district of Sri Lanka. For this purpose, information from 100 paddy farmers has been collected on whether and how they interact with other farmers in their neighbourhood as well as with extension workers. Amongst others, the collected data included information on whether farmers decided to be innovators (first users), early adopters, late adopters, or non-adopters.

The empirical findings reveal that extension officers are perceived as important knowledge sources for the farming community in Sri Lanka. Contrasting the general narrative in the literature (Huffman & Mercier, 1991; Uematsu & Mishra, 2010; Mishra & Park, 2005; Mishra et al., 2009; Roberts et al., 2001; Fernandez-Cornejo et al., 2005), the study does not reveal any significant relationship between the technology adoption behaviours of paddy farmers and their demographic characteristics. In line with existing research (e.g. Samiee et al., 2009; Bonabana-Wabbi, 2002) and in contrast to Abadi Ghadim et al. (2005), the analysis reveals farm size as an insignificant factor in paddy technology adoption. Moreover, the study uncovers the dependency of paddy farmers in Hambantota district on informal communication channels to exchange information, which confirms the research of Just and Zilberman (2002). In sum, the study highlights the importance of formal communication channels for farms in developing countries, which underlines the importance of extension services.

Chapter 6: Factors constraining the adoption of new agricultural technologies by paddy farmers in the Hambantota district of Sri Lanka

Present agricultural technologies are rich with improved mechanisms and practices that can significantly boost the growth of agricultural output (Iain et al., 2009). Therefore, the recent technological revolution in the agricultural sector has substantially contributed to the improvement of quantitative and qualitative production. Most modern agricultural technologies have been invented and successfully adopted in developed countries. In spite of the beneficial aspects of these technologies, rural farmers in developing countries have not been particularly successful in adopting them (Mwangi & Kariuki, 2015; Kasirye, 2010). In fact, the adoption rate of new technologies has been and remains relatively low in most developing countries, which contrasts with the situation in developed nations (Mwangi & Kariuki, 2015; Bandira & Rasul, 2002).

There are diverse factors determining agricultural technology adoption in developing countries (Katungi & Akankwasa, 2010; Akudugu et al., 2012; Loevinsohn et al., 2012; Adesina & Baidu-

Forsen, 1995). Commonly, they are classified into two major groups. The first group includes economic (farm size, cost of adoption, access to credit), social (age, education level, gender), and institutional factors (presence of agricultural extension services) (Akudugo, 2012). The second major group deals with farmers' access to knowledge about new agricultural technologies. However, so far, the literature provides little insight into the relative importance of these factors for agricultural technology adoption in developing countries. The study presented in this chapter attempts to fill this gap by means of an empirical analysis. It thereby contributes to the still underdeveloped literature on factors constraining the diffusion of modern agricultural production technologies in developing countries.

The empirical analysis is based on a sample of 30 extension officers serving paddy farmers in the Hambantota district of Sri Lanka. It investigates their perceptions of farmers' adaptation of new technologies and of the factors that influence the adoption decisions. As an empirical case study, two paddy technology programmes (FFS and Yaya 2) are considered. Specifically, the study seeks to explain the level of adoption of these two programmes by looking at different stages (awareness, interest, evaluation, trial, and adoption) of the adoption process.

The results of the empirical analysis show that the adoption of new paddy cultivation technology by farmers in Hambantota district varies between farming communities from 40 to 60 percent across different adoption stages of the FFS and Yaya 2 programmes. The study thereby confirms what has been reported in previous research (Muange & Schwarze, 2014; Uaiene et al., 2009; Bandiera & Rasul, 2002). These insights are further deepened with multivariate regression analyses that identify 'lack of compatibility', and 'availability of extension services' as relevant obstacles to the adoption of the FFS programme at the awareness, adoption, and discontinuation stages. In contrast, the study does not deliver insights into what factors impact the adoption of technologies promoted by the Yaya 2 programme. Nevertheless, it underlines the importance of a 'second group' of factors, i.e. factors relating to information availability, sharing, and diffusion, at least for one of the two programmes.

With some caution, the study puts forward some policy prescriptions. It appears that extension services do share relevant information about technologies with farmers rather effectively

through the Yaya 2 programme but fail to do so in the FFS programme. Accordingly, the first might serve as an example for the design of future programmes. Nevertheless, the study suggests that poor technical knowledge is still an important constraining factor. Consequently, the educational services of the extension services are advised to focus on improving technical knowledge for farmers going forward.

Chapter 2

The impact of system, coordination, and socialisation capabilities on the absorptive capacity of non-profit research organisations in developing countries

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Abstract: This chapter explores how organisational antecedents shape absorptive capacity (ACAP), focusing on the relationship between system, coordination, and socialisation capabilities, with *potential* and *realised* ACAP. Notably, this study focuses on non-profit-oriented organisations (public R&D institutes) in developing countries, which have received little attention in the literature so far. The data reveals that the ACAP of these institutes are primarily shaped by system and coordination capabilities, and to a lesser extent by socialisation capabilities, whereby coordination capabilities matter to a greater degree for organisations' *potential* ACAP and system capabilities for *realised* ACAP.

Keywords: *Absorptive capacity, Combinative capabilities, Organisational antecedents, Organisational structure, R&D institutes*

2.1 Introduction

In a world that is highly competitive and dynamic, organisations constantly strive to learn and develop capabilities to cope with changes to ensure their survival in markets. Such dynamic competencies are particularly relevant for knowledge-based firms (Eisenhardt & Martin, 2000; Fosfuri & Tribó, 2008; Teece et al., 2003). Cohen and Levinthal (1989) prominently introduced the concept of ACAP to describe these capabilities: essentially, firms' absorptive capacity builds on the ability of their employees to recognise valuable external knowledge, acquiring it and incorporating it into the work process, thereby enhancing work processes and further developing the required organisational capabilities (acquisition, assimilation, transformation, and the exploitation of new knowledge) (Ter Wal et al., 2011).

The application of the absorptive capacity concept in various fields and at various levels of analysis led to the identification of a whole array of factors that influence it. Among those determinants, R&D activities, related prior knowledge, individual skills, organisational structure, and human resource management practices have been thoroughly studied in different organisational settings (Cohen & Levinthal, 1990; Jansen et al., 2005; Lane et al., 2001; van den Bosch et al., 1999; Lane & Lubatkin, 1998; Daghfous, 2004).

Most of the existing research on the determinants of organisational absorptive capacity focuses on profit-oriented organisations. Many of these studies also examine the role of ACAP in relation to business performance and innovation (Cohen & Levinthal, 1990; Fosfuri & Tribó, 2008; Linsu Kim, 1998; Tsia, 2002; Kim, 1998). Other works explore the influence of organisational ACAP on inter-organisational knowledge transfers (Lenox & King, 2004; Schmidt, 2005; Szulanski, 1996) and inter-organisational learning (Giuliani & Bell, 2005; Lane & Lubatkin, 1998; Mowery et al., 1996). However, so far, few insights have been gained as to the determinants of ACAP within service-providing public organisations that operate on a non-profit basis. Existing studies also pay little attention to organisational antecedents such as system, coordination, and socialisation capabilities, which are argued to be crucial determinants in this context (Jansen et al., 2005; Lane

et al., 2001; van den Bosch et al., 1999; Zahra & George, 2002). These gaps motivate the present paper.

The results indicate that many of the variations in organisations' absorptive capacities (*potential* and *realised*) are rather unrelated to organisational antecedents in the context of non-profit organisations in developing countries. However, this study confirms a positive relationship between participation in decision-making processes and *potential* absorptive capacity, which underlines the importance of system capabilities for the development of this dimension of ACAP. With respect to socialisation capabilities, there is some evidence for a positive effect of orientation programmes on *realised* ACAP. Accordingly, while the empirical findings remain somewhat restricted due to data limitations, the data nevertheless confirm the importance of differentiating between *potential* and *realised* ACAP in the context of non-profit organisations in developing countries.

This chapter is structured as follows. In Section 2, the theoretical arguments and formulated hypotheses are elaborated. Section 3 provides details on the data, the specification of variables, and the estimated model. In Section 4, the main findings are presented. Finally, Section 5 discusses the results, the main conclusions, and outlines some suggestions for future research.

2.2 Theoretical background and hypothesis

2.2.1 Absorptive capacity in the literature

Absorptive capacity at the organisational level has a simple definition, classically offered by Cohen and Levinthal (1989) as the 'ability to identify, assimilate and exploit knowledge from the environment'. Later, Lane and Lubatkin (1998) and van den Bosch et al. (2003) confirmed these three components of ACAP (identification, assimilation, and exploitation) as valid and empirically proven, serving as the main prerequisites that ensure a firm's learning ability. Zahra and George (2002) later expanded upon the original concept of ACAP by introducing an additional component named *transformation of knowledge*, by which they meant an organisation's capability to develop and refine the routines that facilitate the combination of existing knowledge with newly

acquired and assimilated knowledge. Organisations' absorptive capacities provide both opportunities and constraints for organisations to improve upon the basis of their accumulated store of knowledge, which is embodied in its general routines and human resources (Giuliani & Bell, 2005).

Given the broadness of the concept, it is no surprise that the conceptualisation of ACAP has changed over the years and differs between researchers. Table 2.6 provides an overview of important studies that have elaborated on the conceptualisation of ACAP. For the purpose of the present paper, the conceptualisation outlined above, which comprises ACAP as four components, is followed. It is simplified, however, according to more recent literature and only *potential* and *realised* ACAP are differentiated. *Potential* ACAP primarily refers to knowledge acquisition and assimilation capabilities, while *realised* ACAP centres on knowledge transformation and exploitation (Zahra & George, 2002, 189). Fosfuri and Tribó (2008) see *potential* ACAP as the mapping of external useful knowledge flows onto internally available information. Consequently, they view *realised* ACAP as the ability to exploit this external knowledge once it has been integrated into or linked to organisations' internal knowledge bases. It must be pointed out, however, that various types of knowledge may require different absorptive capacities, which are abstracted below.

Given the importance of ACAP for organisations' innovation and economic performance, a question is raised as to what influences its development and explains variations in ACAP between organisations. This will be discussed in the subsequent section.

INSERT TABLE 2.6.

2.3 Antecedents of absorptive capacity

2.3.1.1 Organizational antecedents affect the ACAP of organization

The organisational capacity for absorbing new information from external sources depends primarily on the level of prior related knowledge (Cohen & Levinthal, 1990). However, exposure

to related knowledge in itself is not sufficient to enhance ACAP. A number of factors shape the likelihood and effectiveness of this process.

Organizational combinative capabilities

An organisation's combinative capabilities impact the development of ACAP. According to Zander and Kogut (1995), combinative capabilities imply the synthetisation and application of new knowledge to the organisation. Eisenhardt and Martin (2000) explain combinative capabilities as path dependent in their emergence, idiosyncratic in detail, but with some common features. This study follows van den Bosch et al. (1999) and distinguishes three types of combinative capabilities (system, coordination, and socialisation), which will be analysed with respect to their role in organisations' ACAP.

System capabilities

System capabilities are the directions, policies, procedures, and manuals that are used to integrate explicit knowledge. They reflect the degree to which rules, procedures, instructions, and communications are laid down in a formal system. Accordingly, formalisation and routinisation procedures are typical characteristics of system capabilities and establish platforms of organisational action (Galunic & Rodan, 1998). Further, formalised rules and procedures reduce the likelihood that individuals will deviate from established behaviours (Weick, 1979, as cited in Jansen et al., 2005). Therefore, formalisation tends to limit the effort expended in knowledge acquisition and hinders individuals from assimilating new external knowledge. Formalisation also supports the retrieval of knowledge that has already been acquired and internalised (Lyles & Schwenk, 1992). Moreover, formalisation increases the ability of organisational members to ascertain opportunities for the transformation of new external knowledge (Galunic & Rodan, 1998; Zollo & Winter, 2002).

In connection, exploitation is facilitated by formal rules and procedures. Specifically, codified best practices will enhance more efficient knowledge exploitation and implementation (Zander & Kogut, 1995; Lin & Germain, 2003). Thus, formal rules and procedures enhance knowledge

transformation and the exploitation underlying realised ACAP. This includes formal internal communication systems. In contrast to informal communication channels within the organisation, formal communication facilitates the knowledge exchange between individuals, and it eliminates the need for additional communication linking departments and positions. Formal communication systems involve prescribed procedures, formal language, codes, working manuals, schedules, and the organisational information system (Jansen et al., 2005). Prevailing formal communication channels easily transform external knowledge into internal knowledge systems. Therefore, formal communication facilitates both knowledge acquisition and assimilation and positively impacts knowledge transformation and exploitation. Accordingly, (formal and informal) routines of knowledge sharing and dissemination will help organisations to develop their ACAP.

Examples of formalised routines for knowledge acquisition and sharing include planned regular symposiums, workshops, and conferences. These occasions provide simple but powerful vehicles for knowledge sharing and assimilation, in particular with respect to the research outcome of external associates. In some cases, conferences and the like may become platforms of innovation.

According to Cohen and Levinthal (1990), routinised organisational behaviours help to efficiently transform new external data into existing sets of tasks and thereby integrate it into the knowledge base of the organisation. Routinised activities allow for coordinated knowledge exploitation within organisational objectives (Adler et al., 1999). Formalised routines eliminate the need for additional communication and coordination among individuals, subunits, and different departments in the organisation. As a result of the reduced volume of communication, the efficiency of knowledge absorption and sharing is expected to be higher when using formalised system capabilities.

Yet, it should be indicated that there is a danger of over-formalisation, which will reduce flexibility and the explorative space needed for innovation or new knowledge assimilation (see for a discussion Boschma, 2005). However, in the context of developing countries, this is less likely to be an issue, as generally the degree of formalisation is lower (Vega-Jurado et al., 2008). In

addition, the positive aspects of formalisation are emphasised in developing countries. For instance, Subramaniam and Youndt (2005) discuss the role of formal rules and procedures as organisational capital, which enhances knowledge absorption and circulation within organisations. Notably, formalised practices are incorporated by the majority of R&D research institutes in Sri Lanka. Accordingly, the first hypothesis highlights the positive aspects of formalisation.

H1: As an indication of system capabilities, the development of formalised routines and processes enhances organisations' absorptive capacities.

Coordination capabilities

In contrast to system capabilities that manage knowledge and the processing thereof by ex-ante rules and (formalised) procedures, coordination capabilities shape knowledge absorption by means of information linkages between individual members of the organisation. While van den Bosch et al. (1999) find that coordination capabilities have a low potential for efficiency, these capabilities do offer a high potential for the scope and flexibility of knowledge absorption, which underlines their relevance of organisations' ACAP.

Coordination capabilities emerge from a process of interaction (De Leeuw & Volberda, 1996). They are therefore the outcomes of path dependent processes (Jansen et al., 2005) and are accumulated through training and job rotation, nature liaison devices, and participation. Job rotation and training create a dynamic environment in organisations and may enhance staff members' capacity for making mutual adjustments. Crucially, they are important vehicles of knowledge sharing. For instance, through job rotation, employees establish new contacts and learn about different parts of the organisation (Jansen et al., 2005).

Another important mechanism in this context is participation, described here as the extent to which subordinates take part in the decision-making process of their superiors. A low level of participation can result in a low level of knowledge sharing, as there is no need and little possibility for subordinates to share (or care about) the diffusion of information and knowledge. In contrast, a high degree of participation will create richer knowledge architectures within

organisations. Moreover, participation in decision making increases the range of prospective 'receptors' to the environment (Cohen & Levinthal, 1990). These knowledge receptors serve as facilitators for the adoption of new external knowledge. In addition, participation allows for the assemblage of a variety of perspectives, which consequentially also supports the assimilation of new information (Jansen et al., 2005). Similarly, participation in decision making can impact delegated responsibilities and thereby enhance knowledge integration and absorption. However, it is argued that while participation in decision making may facilitate the initiation stage of knowledge acquisition, it may negatively impact the implementation stage (Jansen et al., 2005). This is primarily due to potential difficulties related to the achievement of consensus. Further, Cardinal (2001) shows that participation in decision making hampers information processing efficiency and thereby may decrease ACAP.

Another aspect of coordination capabilities is the forming of task forces. These can serve as an organisational cross-functional interface stimulating lateral forms of communication (Jansen et al., 2005). Establishing task forces within an organisation promotes non-routine and reciprocal information processing. Members of a task force may vary in how they acquire and assimilate external knowledge, which helps in obtaining and integrating broader and more heterogeneous sets of knowledge (Cohen & Levinthal, 1990). As members of the team represent and combine different sets of existing and newly acquired data (Henderson & Cockburn, 1995), task forces can also improve knowledge transformation and exploitation.

H2: While coordination capabilities may generally help organisations to develop higher levels of ACAP, some elements (e.g. participation) may negatively affect organisational-level ACAP.

Socialization capabilities

Socialisation capabilities refer to the ability of firms to produce a brief ideology that offers members an identity as well as a collective interpretation of reality (van den Bosch et al., 1999). Based on the variety of definitions in the literature, socialisation capability is based on a firm's culture and represents a system of ideas (Jansen et al., 2005). Similarly to the case of coordination capability, socialisation capability is also path dependent (Jansen et al., 2005). Socialisation

capabilities contribute to common codes of communication and dominant values (Henderson & Cockburn, 1995; Teece et al., 2003), referencing two aspects of social relations: the structural aspect (e.g. the density of linkages) and cognitive aspect (e.g. shared social experiences) (Jansen et al., 2005). Both of these aspects impact knowledge exchange and learning. For instance, dense internal networks constrain members from seeking information from external knowledge sources. Thereby, they may limit the openness of the organisation to external data and alternative ways of performing organisational tasks (Nahapiet & Goshal, 1998; Sethi et al., 2001). Yet, dense networks may also indicate trust and a cooperative spirit, which fosters the commonality of knowledge (Rowley et al., 2000), stimulating internal communication and knowledge exchange throughout the organisation (Galunic & Rodan, 1998). Therefore, dense networks allow organisations to more quickly and efficiently diffuse as well as exploit new knowledge (Zahra & George, 2002).

Another example of socialisation capabilities is orientation programmes. Such programmes are developed by organisations and are frequently integral parts of familiarisation processes. Orientation programmes offer newcomers access to specific information and encourage their commitment to the goals and procedures of the organisation. In this sense, they contribute to the sharing of information and thereby the overall coherence of an organisation. As Chao et al. (1994) argue, socialisation practices facilitate newcomers' comprehension of background knowledge and their communication with others. They thereby enhance the acquisition of new knowledge and the combination of new and pre-existing knowledge (Zahra & George, 2002).

However, in some instances, such socialisation practices may create mental prisons that prevent people from seeing the need for change (De Leeuw & Volberda, 1996). Generally, a strong culture and belief system resists deviations and changes from the norm and tends to foster an 'inbreeding of ideas' due to reduced exposure to the external environment. Cohen and Levinthal (1990) further argue that socialisation practices hamper the ability to seek external knowledge and impede the organisational ability to acquire and assimilate it. Adding to this, Ashforth and Saks (1996) express their scepticism regarding the possibility for socialisation activities to shape the establishment of interpersonal relationships and subsequently a congruence of rules, needs,

and beliefs among individuals within organisations. However, most of the literature attributes a more positive effect to socialisation practices, which is reflected in the final hypothesis.

H3: Organisational socialisation practices positively contribute to organisations' ACAP.

2.4 Research methodology

The empirical research for this project is based on agricultural R&D institutes in Sri Lanka. While these organisations are similar in their aims of conducting agriculture-related research, they specialise in different subject areas. This study examines the different organisational antecedents discussed above and identifies their impact on the ACAP of these institutes.

The total population of R&D research organisations with a focus on agriculture in Sri Lanka is 36, including public universities and private R&D institutions (ASTI). Of these, the research team was able to interview 29, which represents the empirical basis for the subsequent analysis. In these cases, interviews were conducted with the head of the research body and the head of the administrative body in each R&D institute using a structured questionnaire. In addition to the questionnaire, internal records and annual reports of the institutes were used to collect data on organisations' innovation performances, changes in their organisational structures, and some further information. The questionnaire can be found in the Appendix.[1]

Dependent variables

Potential and realized absorptive capacities

According to Lazzeri and Pisano (2014), the learning and innovation capability of an organisation is primarily determined by its capacity for knowledge acquisition, assimilation, exploitation, and sharing. Therefore, two composite measures of ACAP based on a number of variables are developed. More precisely, the main four dimensions (acquisition, assimilation, transformation,

[1] Detailed information on the questions used for the analysis can be found in the questionnaire attached in the Appendix.

exploitation) of ACAP that have been defined by Zahra and George (2002) are measured. All items are measured on a five-point Likert scale ranging from totally disagree to totally agree. By and large, this relies on existing approaches concerning this questionnaire in the literature (Szulanski, 1996).

Four items are used to assess the intensity and direction of efforts invested in knowledge acquisition. Information was collected about the extent to which R&D institutes interact with each other for the purpose of acquiring knowledge (INTERAC), whether their research officers regularly visit other R&D institutions (VISIT), whether they collect and use information and knowledge by informal means (INFORM), and finally, whether they periodically organise seminars and conferences to acquire knowledge (CONFSEM).

Knowledge assimilation (ASSI) is measured with two variables, analysing how efficiently R&D institutes reorganise their research activities with respect to existing research problems (REORAG) and how quickly they grasp new knowledge and technologies (KWG_TECH).[2]

Four items calculate the transformation (TRANS) dimension of ACAP, assessing the extent to which the institute's strategies are able to facilitate the recognition of opportunities to improve existing operations, structures, and strategies (Zahra & George, 2002). More precisely, the measurements compute whether R&D teams regularly consider the impact of new technologies and knowledge on agriculture development (AGRI_DEV), whether research officers in the organisations record and store newly acquired knowledge for future references (RECO_STOR), whether research officers quickly share practical experiences with other researchers (SHARE), and finally how fast external opportunities are accepted for the application of new knowledge (EXT_KWG).

In addition, five variables are used to assess the extent to which organisations are able to exploit new external knowledge (EXPLO). The first variable considers the presence of a clear division of roles and responsibilities within the organisation with respect to the application of the new knowledge (ROLES). The second measures the awareness of researchers as to how R&D activities

[2] More precise questions can be found in the Appendix.

are performed within their research institutions (AWARE). The third variable approximates how the organisation attempts to exploit external knowledge (EXP_KWG). A fourth consideration is whether an organisation faces difficulties in the adoption of new technologies and knowledge (DIFF). The final variable captures the research culture of the R&D institutes with respect to knowledge creation and dissemination (CULTURE).

Table 2.7 depicts the correlations among the variables used to approximate different aspects of *potential* and *realised* ACAP. Further descriptions of the questionnaire are presented in Annex 2.A.

Independent variables

To test the hypotheses, four sets of explanatory variables are created. Three sets are defined that capture the different types of capabilities (system, coordination, socialisation). System capabilities are measured on the basis of formalisation and routinisation practices existent in the institution, which are captured by the following three variables: the existence of formalised rules and procedures to conduct research activities (FORM_RULE), the existence of a formal communication system in the organisation (FORM_COMM), and the presence of routinised work plans for research activities and information sharing processes (ROUT_PLAN).

Coordination capabilities are measured with two variables. Firstly, the degree is captured to which staff members participate in decision-making processes (PARTICI). Secondly, organisations are assessed in terms of their use of task forces in research activities (TASKFORCE).

Four variables are utilised to measure socialisation capabilities. The first considers whether R&D researchers have established linkages with other researchers in their own institute (NETWORK 1). The second captures the extent to which relationships are formed with researchers of other organisations (NETWORK2). Moreover, the presence of orientation programmes for newcomers (ORIENT) and the existence of platforms through which to share information (PLATFORM) are included.

Control variables

The size of an organisation is frequently argued to impact an organisation's ACAP (Jansen et al., 2005). Organisations with numerous employees tend to have more human capital to absorb and use new knowledge. Thus the first control variable considers the number of employees of organisations (SIZE).

Moreover, the numbers of departments within the institutes (DEPT) is included, as a larger number is likely to indicate the greater general research capability of the organisation. However, a smaller number might signal specialisation in a particular field. Consequently, it will have a greater ACAP with respect to this field. Another control variable is the age of an organisation (AGE), which is measured by the number of years since its establishment. Research has shown that older organisations differ in their abilities regarding knowledge acquisition and exploitation (Autio et al., 2000), which will be controlled for by this variable. The educational qualifications of employees are also crucial to understand knowledge management processes. Hence, it is assumed that an organisation's ACAP improves with more qualified employees. Thus, each of the following is measured: the number of employees in the organisation who have at least obtained a Bachelor's degree (EDU_BSc), a Master's degree (EDU_Master), or a doctoral qualification (EDU_PhD).

In addition, institutes are categorised according to their research output. That is, the numbers of scientific publications (PUBL) and new patents (PATS) produced by employees in 2015 and 2016 are considered. It is further assumed that R&D contracts with other research organisations (R&D CONTR) improve organisational ACAP. Similarly, R&D collaboration projects (R&D COL), which organisations participated in during 2015 and 2016, are expected to help widen their knowledge bases. Accordingly, R&D contracts are accounted for based upon the number of R&D contracts signed with other research organisations during the period 2015–2016. Straightforwardly, the number of R&D collaboration projects undertaken with other organisations during this period is measured. Table 2.1 summarises and presents the descriptive statistics of the above variables.

	N	Min	Max	Mean	S.D.
SIZE	29	1.00	108.00	26.206	25.36361
DEPT	29	1.00	13.00	5.3793	2.79558
AGE	29	5.00	130.00	50.413	35.20503
EDU_ BSc	29	0.00	23.00	5.8621	4.69593
EDU_MSc	29	2.00	36.00	10.758	7.94020
EDU_PhD	29	0.00	82.00	10.758	16.76232
PUBL	29	0.00	426.00	45.965	90.49526
PATS	29	0.00	7.00	0.8276	1.69177
R&D CONTR	29	0.00	42.00	3.5517	7.82207
R&D COL	29	0.00	8.00	0.6897	1.62796
ACAP	29	2.34	3.56	2.9245	0.29138
Valid N (list-wise)	29				

Table 2:1 Descriptive Statistics of organizational characteristics

Source: Author's own data, 2017

Crucially, organisational structure is approached from a dynamic perspective in contrast to its rather frequent static conception. That is, this project captures to what extent organisations are able to adapt to evolving environments and circumstances. Hence, to capture differences between organisations' abilities of adapting their organisational structures in responds to a changed environment, information is collected on whether they have implemented any structural changes (STRUC) or adapted their internal information system (INFOS). Annex 2B provides the details on the formulation of the questions.

Consideration is also given toward the general structures and forms that shape the knowledge processing system of an organisation (Lane & Lubatkin, 1998). The organisational form provides a basic infrastructure, which enables in specific ways the processes of evaluating, assimilating, integrating, and utilising knowledge (van den Bosch et al., 1999). In this context, the focus is particularly on how changes of organisational form over time impact an organisation's focus on internal or external knowledge sources. Organisations are assessed based upon what structural changes they have completed during last few years to improve their knowledge processing activities. Since several variables are used as measurements, the most important component is extracted using principle component analysis (which explains the 35 percent of variance among

individual variables): changes in department arrangement (ARRANG), formation of new working groups (GROUP), changes in managerial roles and activities (MANROLE), changes in information sharing processes and strategies (SHARING), and changes in research fields or thematic areas (RFIELD). For a list of all variables, see Annex 2.E.

2.5 Research findings

This study analysed the impact of three types of capabilities, specifically system, coordination, and socialisation capabilities, on the ACAP of research institutes. This is done with a stepwise regression approach. While the dependent variables are theoretically restricted to a specific interval, their values (and those predicted by the models) never reach the lower or upper bounds. Accordingly, they are treated as continuous variables and OLS regression techniques are employed. Given the sample of 29 observations, a stepwise regression approach is used.

Therefore, the normal distribution of error terms of the dependent variables of the models are tested, employing a Shapiro-Wilk test to test normality since the sample size is less than 50. The test results supported only knowledge transformation (TRANS) while the other three dependent variables do not support an assumption of normality.[3] Further, the values of deviations from the linearity were used to test the presence of linearity. All the models of the regression analysis have shown the linear relationships except ACQ* TASKFORCE (p=0.33), ASSIMI*NETWORL 1 (p=0.036), and TRANS*NETWORK 2 (p=0.031). However, these deviations were only minor issues in visual inspections. Moreover, multi-collinearity and homoscedasticity were not an issue in this analysis (see Annex 2D).

Tables 2.2 to 2.5 illustrate the results of the stepwise regression analysis and model summary. Coefficient tables elucidate the significant explanatory variables and the four dependent variables: knowledge acquisition (ACQ), assimilation (ASSIMI), transformation (TRANS), and

[3] ACQ (SW=0.873, p<0.05), ASSIM (SW=0.883, p<0.05), TRANS (SW=0.951, p>0.05), EXPLOI (SW=0.878, p<0.05).

exploitation (EXPLOI), whereby the first two represent potential absorptive capacities and the latter two potential absorptive capacities.

Table 2.2 shows the model summary for knowledge acquisition. The regression identifies three significant explanatory variables yielding a combined R^2 of 0.644. The three variables are DEPART, REFEIDL, and WORKGRP. Accordingly, the number of departments (DEPART), changes in research areas (REFEIDL), and the formation of new working groups (WORKGRP) are significantly related to knowledge acquisition. Interestingly, the coefficients of DEPART and WORKGRP are negative, which suggests that rather streamlined organisations (smaller organisations with fewer departments) and those that do not form new working groups are better in terms of knowledge acquisition activities. In contrast, organisations that are able to change their thematic focus (REFEIDL) benefit from this for their knowledge acquisition abilities.

Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.523[a]	.273	.246	.20628
2	.734[b]	.538	.503	.16757
3	.803[c]	.644	.602	.14995

a. Predictors: (Constant), DEPART
b. Predictors: (Constant), DEPART, RFIELD
c. Predictors: (Constant), DEPART, RFIELD, WORKGRP

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.567	.084		6.727	.000
	DEPART	-.044	.014	-.523	-3.185	.004
2	(Constant)	.512	.070		7.326	.000
	DEPART	-.048	.011	-.566	-4.229	.000
	RFIELD	.270	.070	.517	3.862	.001
3	(Constant)	.480	.064		7.545	.000
	DEPART	-.038	.011	-.445	-3.491	.002
	RFIELD	.385	.075	.737	5.106	.000
	WORKGRP	-.228	.083	-.417	-2.733	.011

a. Dependent Variable: ACQ

Table 2:2 : Model summary and coefficient values for knowledge acquisition process

Source: Author's own data, 2017

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.575[a]	.331	.306	.35081
2	.672[b]	.451	.409	.32368

a. Predictors: (Constant), PARTICI

b. Predictors: (Constant), PARTICI, FORM_RULE

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.646	.386		4.267	.000
	PARTICI	.433	.119	.575	3.653	.001
2	(Constant)	2.294	.447		5.127	.000
	PARTICI	.461	.110	.612	4.192	.000
	FORM_RULE	-.246	.103	-.349	-2.391	.024

a. Dependent Variable: ASSIMI

T**able 2:3 : Model summary and coefficient values for knowledge assimilation process**

Source: Author's own data, 2017

Table 2.3 displays the model for knowledge assimilation (ASSIMI), which yields a final R^2 of 0.451. The significant explanatory variables are participation in decision-making processes (PARTICI) and the formalisation of rules and procedures (FORM_RULE), whereby the first obtains a significantly positive and the latter a significantly negative coefficient. Participation in decision making provides a better avenue for knowledge assimilation, and the more formalised rules and procedures constrain the assimilation of external knowledge into the existing knowledge base.

In sum, organisations are found to improve their absorptive capacities when they refrain from creating new departments and workgroups as well as refusing to formalise their knowledge acquisition and assimilation processes. In addition, being flexible and able to venture into new research topics, as well as creating possibilities for employees to participate, strengthens their capacity to absorb knowledge. Consequently, beneficial system capacities are based on organisations maintaining flexibility and adaptability in their knowledge absorption processes regardless of changing contexts.

Table 2.4 presents the model for knowledge transformation (TRANS), which exhibits an R^2 value of 0.404. The two significant explanatory variables in this model are significantly related to knowledge transformation: the number of Bachelor's degree holders (BSC) and the number of

publications (PUBL) during the years 2015–2016. While the BSC obtains a significant positive value, PUBL shows a significant negative value. This suggests that organisations with Bachelor's degree-qualified researchers perform well when transforming external knowledge into an internal knowledge base. Furthermore, the creation of more research output in terms of scientific publications has been negatively affected by the knowledge transformation process within the research institutes.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.503[a]	.253	.225	.37158
2	.635[b]	.404	.358	.33840

a. Predictors: (Constant), BSC

b. Predictors: (Constant), BSC, PUBL

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.718	.112		24.360	.000
	BSC	.045	.015	.503	3.025	.005
2	(Constant)	2.724	.102		26.807	.000
	BSC	.059	.015	.660	4.040	.000
	PUBL	-.002	.001	-.418	-2.560	.017

a. Dependent Variable: TRANS

Table 2:4 : Model summary for knowledge transformation process

Source: Author's own data, 2017

Table 2.5 presents the model for knowledge exploitation (EXPLO), which yields a final R^2 of 0.546. The significant explanatory variables are routinised work plans (ROUT_PLAN), changes in the research field (RESFIELD), and the formalised rules and regulations of the organisation (FORM_RULE). All of these variables show significant positive values. Therefore, organisations are found to improve their absorptive capacity in the presence of routinised work plans for research activities and the information sharing process. Changes in the research focus and the

presence of formalised rules and regulations within the research organisation also improve its absorptive capacity.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.596[a]	.355	.331	.29452
2	.682[b]	.466	.424	.27316
3	.739[c]	.546	.491	.25684

a. Predictors: (Constant), ROUT_PLAN
b. Predictors: (Constant), ROUT_PLAN, RFIELD
c. Predictors: (Constant), ROUT_PLAN, RFIELD, FORM_RULE.

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.001	.275		7.267	.000
	ROUT_PLAN	.343	.089	.596	3.854	.001
2	(Constant)	1.833	.265		6.907	.000
	ROUT_PLAN	.374	.084	.650	4.473	.000
	RFIELD	.267	.115	.337	2.321	.028
3	(Constant)	1.472	.303		4.855	.000
	ROUT_PLAN	.308	.085	.536	3.647	.001
	RFIELD	.284	.108	.359	2.623	.015
	FORM_RULE.	.185	.088	.307	2.100	.046

a. Dependent Variable: EXPLOI

Table 2:5: Model summary and coefficient values for knowledge exploitation process

Source: Author's own data, 2017

Accordingly, it is found that the potential absorptive capacity of organisations has been improved by changing the thematic areas of research and participation in decision-making processes. In sum, potential absorptive capacity of the organisation has been affected by both the coordination and system capabilities of the organisation. Moreover, organisations are found to improve their realised absorptive capacity through the number of qualified research staff,

changing their research theme, and following routinised and formalised research activities. In sum, the system capabilities of organisations are more relevant to improve their realised absorptive capacity.

2.6 Discussion and Conclusion

There have been a great number of studies analysing the organisational factors behind differences in the absorptive capacity of organisations (Gold et al., 2005; Grant, 1996; Jansen et al., 2005; Lane & Lubatkin, 1998; Lazzeri & Pisano, 2014; Subramaniam & Youndt, 2005; van den Bosch et al., 1999, 2003). However, we still know little about the determinants of ACAP within service-providing state organisations that operate on a non-profit basis, particularly in developing countries. The gap becomes even more pronounced when differentiating between the two types of ACAP: *realised* and *potential* (van den Bosch, 1999; Lane et al., 2001; Zahra & George, 2002; Jensen et al., 2005). The present chapter fills this gap. Consequently, it investigates how organisational combinative capacity impacts the *potential* and *realised* ACAP by focusing on knowledge acquisition, assimilation, transformation, and exploitation independently. Moreover, the impact of organisational structural changes are also investigated using a sample of 29 agricultural R&D institutes in Sri Lanka.

In the context of agricultural R&D institutes in Sri Lanka, this study reveals that organisational mechanisms associated with combinative capabilities relate to organisational PACAP and RACAP in different ways. According to the stepwise regression analysis, the knowledge acquisition process of R&D institutes depends on the number of departments, changes in research focus, and the formation of the working group in the organisations. Based on the research findings, changing a research theme is a more important factor to improve knowledge acquisition, as is the exploitation process of the research organisations. Fewer number of research department also help to improve knowledge acquisition. A possible explanation for this is that utilisation of organisational resources (research funds, skilled staff, laboratory facilities, etc.) among few research departments is more efficient than utilising them among many. Moreover, forming a

specific working groups for research activities does not seem an effective approach to acquire external knowledge.

According to this research, participation in the decision-making process improves the knowledge assimilation of R&D institutes. In contrast, participation has a positive association with the knowledge acquisition process, as noted by Jansen et al. (2005). Furthermore, formalised rules and regulations are negatively associated with knowledge assimilation. Vega-Jurado et al. (2008) have found a positive impact of formalisation on the knowledge acquisition process in the organisations.

In terms of knowledge transformation, the number of employees with Bachelor's degree qualifications positively contributes to transforming external knowledge into internal context. One possible explanation would be that the education level of the employees will strengthen the individual capacity of researchers in generating new knowledge by transferring external knowledge.

However, according to this study, the innovation output of the organisation in terms of scientific publication prevents the transfer external knowledge. This is a rather striking finding: generally it is supposed that researchers producing publications incorporate external knowledge for their research activities. Instead, the higher number of research publications of the organisations shows their scientific potential and therefore improves the absorptive capacity (Vega-Jurado et al., 2008).

Importantly, knowledge exploitation has positively improved through routinised planning, formalised rules and regulations, and changes in the thematic area of research activities. This may be because routinised work plans establish definite behaviour patterns which facilitate the pre-planning of activities. This provides an efficient organisational structure which provides collective action to improve absorptive capacity. Furthermore, formalisation also improves the knowledge integration mechanism (Lane & Lubatkin, 1998).

In particular, the creation of formal rules, as one expression of system capabilities, seems to help *realised* ACAP but not *potential* ACAP. This result is also supported by Jansen et al. (2000), who report a rather negative impact of formal rules and procedures on *potential* ACAP. Coordination

capabilities, as covered by the participation of employees in organisational processes, support the development of *potential* ACAP. With respect to participation, this corresponds very much to the expectations of this project. This finding might reflect the coordinated efforts of the agriculture research institutes in Sri Lanka.

Sri Lankan R&D institutions involve intensive collaboration between their research teams, research planning teams, and research monitoring and evaluation teams from the beginning of the research project until the end of implementation process. It also complements Cohen and Levinthal (1990), who have argued that participation is a means of increasing the number of 'knowledge receptors' in the external environment. Thereby participation allows linkages with other research institutes. Therefore, the research findings support the argument that coordination capability supports the assimilation of new knowledge. This also applies to participatory decision making and project teamwork, which are common practices in many research institutes in Sri Lanka.

With respect to system capabilities, in particular routinised plans and procedures, many R&D institutes in Sri Lanka hold annual events where they share knowledge with external research institutes. Annual symposia and conferences are also organised regularly by agricultural universities in Sri Lanka. Moreover, the Ministry of Agriculture coordinates periodic meetings with all agricultural research institutes to share important information. These systematic efforts translate at the organisational level to the majority of research organisations having well-planned and regular annual programmes to share and exploit new knowledge.

In sum, this study clearly confirms the importance of the system and coordination capabilities and differentiated impact on *potential* and *realised* ACAP. However, it is unable to confirm a substantial contribution of socialisation capabilities to organisational absorptive capacity. In contrast, Jansen et al. (2005) have reported a strong and positive effect of socialisation capabilities on *potential* ACAP in relation to network connectedness. The authors argue that network connectedness enhances the overall access to diverse knowledge sources. Despite this, the results related to high network connectedness (0.45 network density) among R&D institutes in Sri Lanka (Silva & Broekel, 2019) indicate that it does not affect organisational absorptive

capacity. This contrasts with the arguments of Cohen and Levinthal (1990) and Morrison (2002), who all maintain that dense networks motivate participants to assist each other and facilitate two-way interaction. These interactions help to improve the knowledge acquisition and assimilation process.

It should be noted that these results are conditional on a number of limitations. Firstly, much of the empirical data were self-reported by department heads or directors of the R&D institutes. Although several precautions were taken to overcome the personal biases of respondents to the questionnaire, the issues of key informant bias cannot be fully eliminated. Secondly, the empirical analysis involves the development of new approximations of the two dimensions of ACAP (*realised* and *potential*). While conducting a validity analysis of these measurements, future research should expand on these and confirm their usefulness in different contexts.

Study	Unit of analysis	Sample/ data	Theoretical Background	Methodology/ Modelling	Measurement	Outcome
Cohen and Levinthal (1990)	Firm's level	1719 business Units using cross sectional survey	Organizational learning and innovation	ACAP is used as determinant of innovative activities	R&D intensity: firm's internal mechanism for knowledge sourcing	Benefit of ACAP is intangible and indirect and vague in determining optimal investment on R&D for developing ACAP. R&D creates a capacity to assimilate and exploit new knowledge.
Lane & Lubatkin (1998)	Inter-organizational	48 Pharmaceutical and 23 biotechnology firms	Organizational learning theory	ACAP as predictor of organizational learning in an alliance dyad	8 total measures based on valuing new knowledge , assimilating new knowledge and commercialization of new knowledge	Relative similarities between two firms' basic knowledge, lower managerial formalization, research centralization, compensation practices and research communities are more powerful than established ACAP and R&D spending.
Van den Bosch et al. (1999)	Firm level analysis	Case study analysis using two firms	Knowledge management and learning theory	Organizational forms and combinative capabilities as major determinant of ACAP: Effect of ACAP on firms' knowledge environment.	3 basic types of component knowledge were focused on; Product/ service related, production process related & market related.	Transition in organizational forms and socialization capabilities facilitate knowledge absorption.
Tsai, W (2001)	Firm unit level	60 business units	Organizational learning	Central network position is dependent on firm's ACAP and access of new knowledge on ACAP.	Innovation achieved rate to measure performances. R&D intensity to measure ACAP and no of employees and unit sales.	Interaction between ACAP and network position are significant.
Zahra and George (2002)	Firm level analysis	Literature review	Knowledge management	ACAP as combination of two subsets; PACAP and RACAP	-	-

Giuliani and Bell (2004)	Firms in a cluster	28 firms	Knowledge management	Impact of firms' ACAP on intra and extra cluster learning	Social network analysis, R&D intensity, external linkages, education level and experiences of employees	Network position of the firm is characterized by the ACAP of the firms and is not evenly distributed in cluster.
Lenox and King (2004)	Firm level analysis	311 firms	Knowledge management	Impact of information provision on ACAP of firm	Cumulative adoption of prevention practices, information provision, past events, related practices, compensation.	Managers can directly affect firms' ACAP through information provision. Information provision cannot fully replace prior experiences.
Tobias Schmidt (2005)	Firm level analysis	4500 manufacturing firms	Knowledge management	R&D activities and stimulation of HRD as determinant of ACAP. ACAP depends on the different types of knowledge.	R&D activities, prior knowledge and individual skills, organizational structure and HRM Practices	Continuous R&D engagement is relevant to ACAP. More R&D expenditure helps to develop the knowledge and skills necessary to source external knowledge. R&D intensity has positive effect on ACAP
Jensen et al. (2005)	Firm level analysis	462 general managers	Organizational management	Impact of organizational mechanism on both potential and realized ACAP	Variables have been developed under three organizational capabilities: Coordination, system and socialization capabilities. Cross functional interface, participation, job rotation, formalization & routinization, structural aspects and cognitive aspects	Coordination mechanism primarily enhances PACAP, while socialization capabilities increase RACAP.

Fosfuri and Tribo (2008)	Firm level analysis	2464 firms	Knowledge management and Innovation management	R&D cooperation and experience with knowledge search as determinant of PACAP.	Innovation performances, Contracted R&D and R&D collaboration, SIMs activities, number of employees, export intensity, total expenditure in internal R&D activities and industry concentration.	Firms with more R&D collaborations and market based transaction in R&D strongly assimilate external knowledge. Experience with knowledge search is a key antecedent of PAC. Higher PAC positively affects innovation. Dynamic Organizational movements & strategies show high impact on PAC.
Vega –Jurado et al. (2008)	Firm level	84 firms	Knowledge management	ACAP is determined by R&D and three major determinants: Organizational learning, formalization and social integration mechanism.	Level of HR training, the degree of assimilation and dissemination of technology, management practices, the level of education of the workforce and mean of seniority of workers.	R&D expenditure is not the best criterion to test ACAP of firms.
Abreu et al. (2012)	Firm level	2 firms	Innovation management	Sectoral and technological specificities influence ACAP, which leads to regional innovation.	Human capital, management practices and use of network to access ACAP of organization.	National and overseas collaborations have a substantial impact on goods & product innovation, while national collaborations are most important for service innovation. Training programs enhance innovativeness and technology awareness of both scientific and support staff.

Table 2:6 : Conceptualization of ACAP in different dimensions

Scale	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. ACQS	2.63	0.51	1												
2. ASSI	3.03	0.42	0.51**	1											
3.TRANS	2.98	0.42	0.29	0.43*	1										
4. EXPLO	3.04	0.36	0.03	0.04	0.29	1									
5. FORM_RUL	3.00	0.59	- 0.12	-0.28	0.07	0.46*	1								
6. FORM_COMM	3.24	0.68	-0.12	-0.21	0.04	0.27	0.35	1							
7. ROUT_PLAN	3.03	0.62	0.09	0.13	0.24	0.59**	0.38*	0.31	1						
8. PARTICI	3.20	0.55	0.45**	0.57**	0.36	0.24	0.12	0.14	0.49*	1					
9. TASKFORCE	2.75	0.89	0.23	0.12	-0.11	0.35	0.27	-0.07	0.41*	0.33	1				
10.NETWORK1	3.03	0.68	0.06	0.06	-0.21	0.40*	0.00	0.05	0.50	0.26	0.56**	1			
11.NETWORK2	2.89	0.48	-0.20	0.19	0.03	0.31	-0.12	-0.13	0.25	0.21	0.44**	0.55**	1		
12.ORIENT	2.55	0.63	0.39	0.26	0.47**	0.24	0.19	0.01	0.31	0.47*	0.25	0.12	0.19	1	
13.PLATFORM	2.79	0.62	0.29	0.09	-0.01	0.46*	0.19	0.12	0.57*	0.33	0.43*	0.44*	0.39*	0.30	1

*Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 2:7: Mean values, Standard Deviations and Correlations

Source: Author's own data, 2017

Annex 2.A

	Knowledge acquisition (AQUS)
1	Our institution has frequent interactions with other main research institutions in the agriculture sector to acquire new knowledge. (INTERAC)
2	Research officers of our institution regularly visit other research institutions for knowledge seeking activities. (For review meetings, for site visits, etc..,) (VISIT)
3	We collect information and knowledge through informal means (e.g. informal discussion, talks with other researchers, through personal relations ...etc.). (INFORM)
4	Our institution periodically organizes seminars and conferences to meet other researchers to exchange ideas and acquire new knowledge. (CONFSEM)
	Knowledge assimilation (ASSI)
5	We are very efficient at recognizing new research problems in the agriculture sector. (always address the existing research problems in the sector) (REORAG)
6	New knowledge and technology are quickly grasped by our research officers. (KWG_TECH)
	Knowledge transformation (TRANS)
7	Our research team regularly considers the impact of new technologies and knowledge on agricultural development. (AGRI_DEV)
8	Research officers in our institution record and store newly acquired knowledge for future reference. (RECO_STOR)
9	Research officers readily share practical experiences with other researchers. (SHARE)
10	As a research team, we quickly grasp any opportunities that may arise for our institution from other external knowledge. (EXT_KWG)
	Knowledge exploitation (EXPLO)
11	Our organization has a clear division of roles and responsibilities as a research institution. (ROLES)
12	It is clearly known by our research team how R&D activities within our institution should be performed. (AWARE)
13	We constantly consider how to better exploit knowledge gained from other external sources (Regular meetings, scientific discussions, etc.) (EXP_KWG)
14	Our institution does not have any difficulties in adopting new technologies and knowledge. (DIFF)
15	Research officers have a common research culture regarding knowledge**/** technologies creation and dissemination. (CULTURE)

Table.2:8: Scale items used to measure potential and realized ACAP

Annex 2.B

Changes in organizational structures
1. Changes of managerial hierarchy (MGTHE)
2. Changes in departmental arrangement (ARRANG)
3. Internal transfer of employees to different job positions (job rotation) (JOBROT)
4. Change in communication channels/ information flow within institution (progress meeting, research presentation, review meeting, etc.) (COMMCHAN)
5. Formation of new working group (GROUP)
6. Change in managerial roles and activities (MANROLE)
Activities performed to re-organize institutional internal information systems
1. Changes in information sharing process and strategies (SHARING)
2. Changes in research area/ field (RESFIELD)
3. Increase in research fund (RESFUND)
4. Prioritization of research areas (PRIOR)
5. Providing incentives for research activity (INCENT)
6. Providing more training for research staff (TRAIN)

Table 2:9: Scale Items used to measure different organizational forms

Annex 2.C

	System capabilities
1	Our institution has formalized rules and procedures to undertake research activities within institution. (research area, limit of scope and budget, IPR issue) (FORM_RULE)
2	We formally communicate relevant information to all research officers in the institution. (information on research grant, training workshop , international conferences and opportunities etc. through public communication channel) (FORM_COMM)
3	We have a routinized plan for carrying out research activities, sharing information within and among research institutions. (periodic progress review, symposium, conferences etc.) (ROUT_PLAN)
	Coordination capabilities
5	We ensure participation of all research officers when making institutional decisions on research and all other institutional activities. (when making R & D activity, developing research proposals etc. (PARTICI)
6	We form task forces or teams to perform research activities. (planning team, project team, monitoring team etc) (TASKFORCE).
	Socialization capabilities
7	Our research team is networked with other internal departments to share knowledge.(joint programme, activities etc., annual gathering) (NETWORK 1).
8	Our research team is networked with other external sources to acquire and share knowledge. (annual gathering with other researchers, symposiums etc.) (NETWORK2).
9	We provide a complete orientation programme for newcomers to the institution to apprise them of the organization and its research culture. (ORIENT)
10	Research team frequently joins a common platform of researchers to share their experiences. (PLATFORM)

Table 2:10: Scale Items used to measure combinative capabilities

Annex 2.D

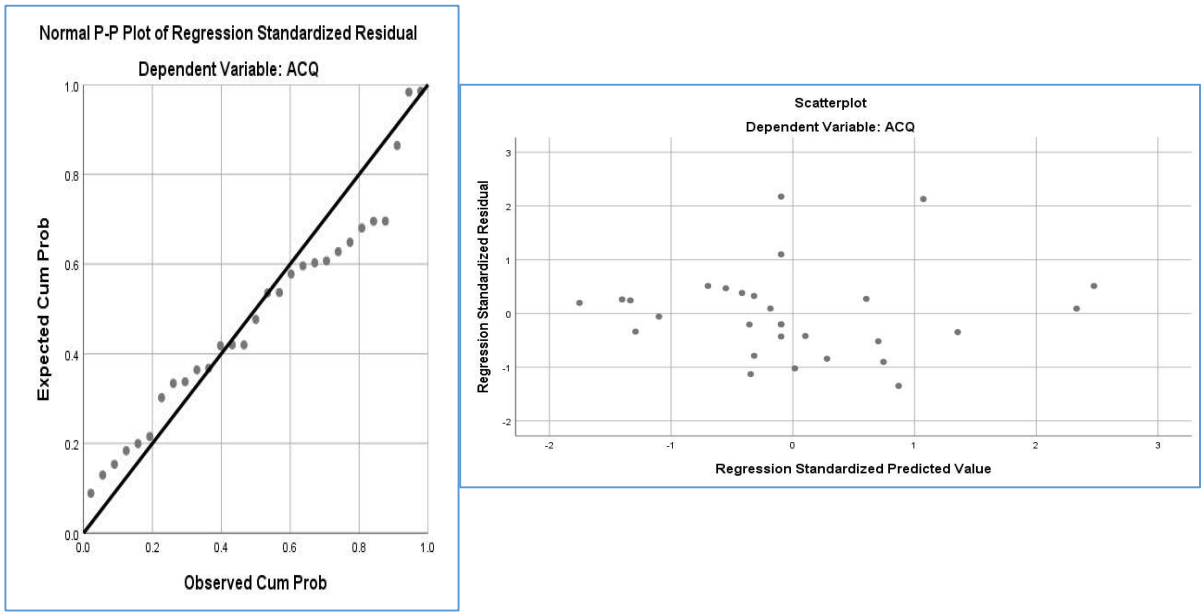

Figure 2:1 Knowledge acquisition

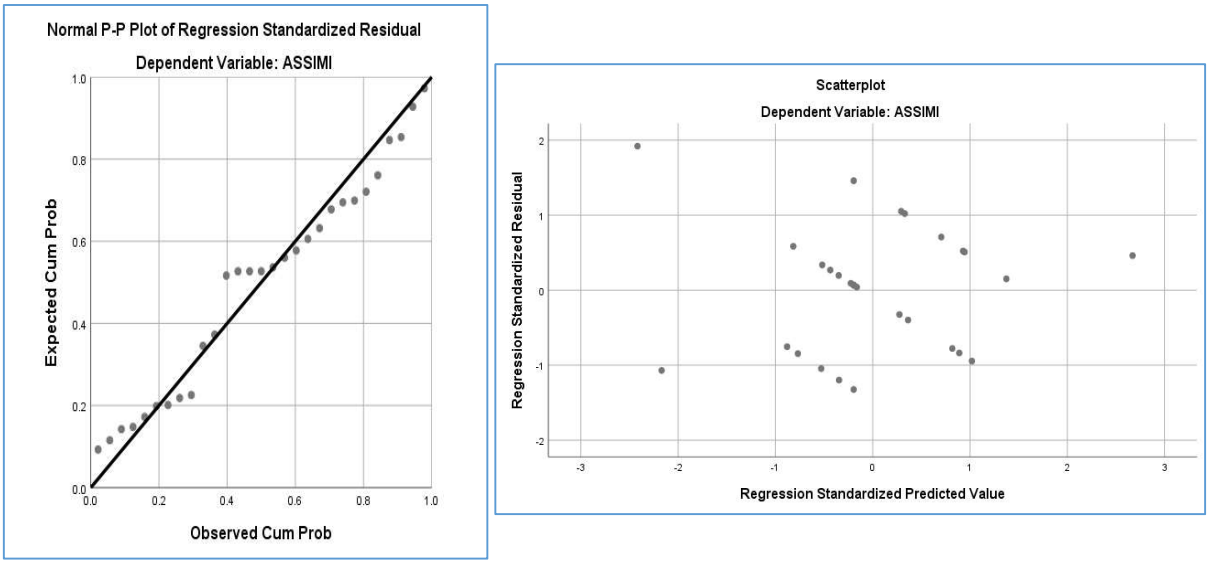

Figure 2:2 Knowledge assimilation

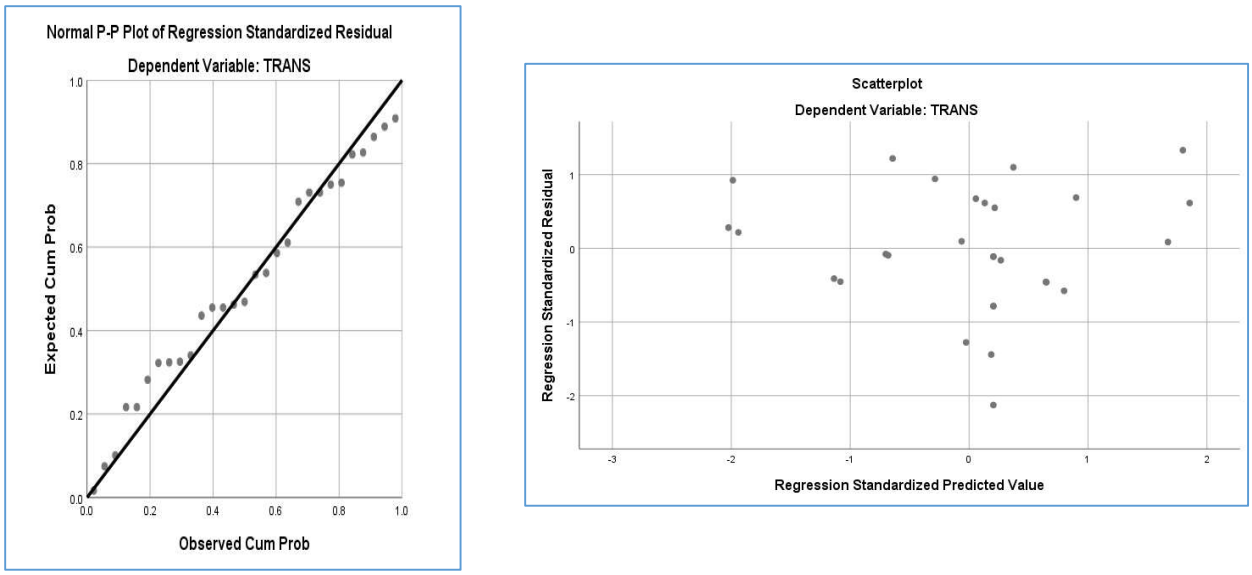

Figure 2:3 Knowledge transformation

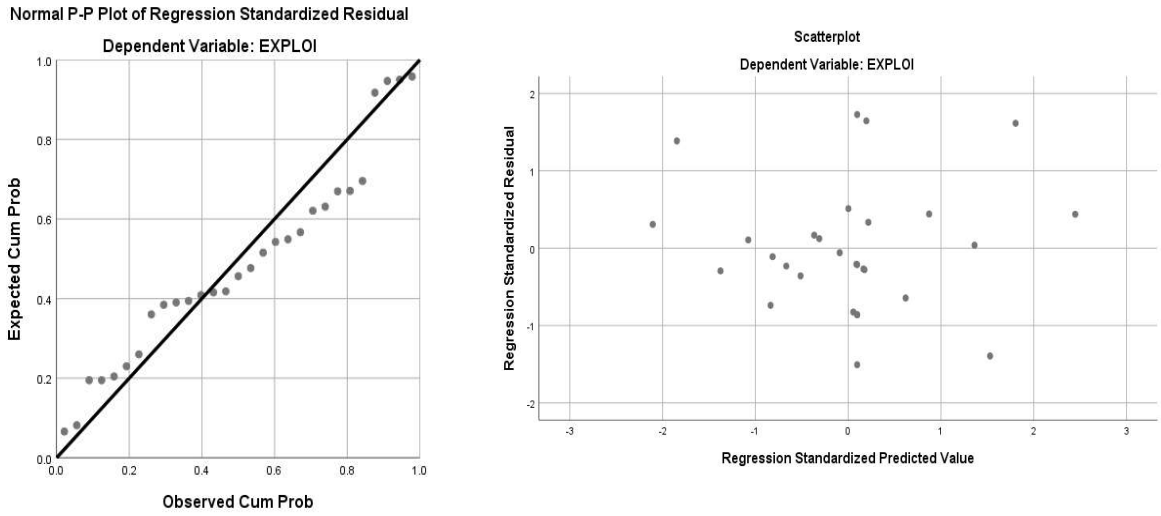

Figure 2:4 Knowledge exploitation

Annex 2.E

Research survey questionnaire

Organizational determinants of absorptive capacity (ACAP): How it matters for knowledge sharing performance

This questionnaire is comprised of three main parts, which follow three broad objectives. Therefore, the questionnaire is structured into 3 main parts. The first part contains some general information about the R & D institutes being surveyed. The second part collects information about the absorptive capacity of the institutes in the context of organizational structure. The third part focuses on measurement of the absorptive capacity of the institutions in the context of combinative capabilities.

1. General information

Name of the organization			
No. of full time researchers		No. of research departments	
Year of establishment		No. of researchers with University degree	
No. of researchers with master degree		No. of researchers with PhD degree	
No. of researchers with diploma qualification			

1.1. Institution's innovation performance

I. Please indicate the number of research papers published and patents obtained or pending due to research activities of your institution during the period 2014-2016.

Number of publications		Number of patents	

II. Did your institution acquire any external R & D contract during the period 2014-2016?

Yes		No	

If yes, How many: ……

III. Did your institution sign any R & D co-operation agreement with any other research institution during the period 2014-2016?

Yes		No	

If yes, How many: ……

IV. If so, what are the 5 most important R & D agreements?.....

1……

2……

3……

1.2. Importance of external sources as knowledge base

Please indicate the importance of the following external sources for the R & D activities and knowledge sharing process of your institution during the years 2014-2016.

External source	Highly important	Important	Less important	Least important	Not important
Public R & D institutions(other non-related research institutions)					
Competitive R & D institutions (similar to your research area)					
Conferences (National/International)					
Scientific forum/meetings					
Scientific journals					
Exhibitions					

Any other (please specify):…….

1.3. Importance of R&D collaboration as a knowledge source

External source	Highly important	Important	Less important	Least important	Not important
Competitive R&D					
Private R&D organizations					
Universities					

2. Organizational form and absorptive capacity

2.1. Did your institution undertake any changes in organizational structure/ design during the period to increase the research capacity of your institutes 2014-2016?

Yes		No	

2.2. If so, what is the nature of these changes?

Change in organizational structure or managerial hierarchy	
Change in departmental arrangement	
Internal transfer of employees to different job positions (job rotation)	
Change in communication channels/ information flow within institution (progress meeting, research presentation, review meeting etc.)	
Formation of new working group	
Change in managerial roles and activities	

Any other (please specify):…….

2.3. Did your institution reorganize your institution's internal information system within the institution during the 2014-2016?

Yes		No	

2.4. If so, what are they?

Any other (please specify): ……

Changes in information sharing process and strategies		Prioritize research areas	
Changes in research area/filed		Give incentives for research activity	
Increase in research fund		Allocate more training for research staff	

2.5. Measuring institutional absorptive capacity

Please indicate your opinions on the following scale items

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Knowledge acquisition					
Our institution has frequent interactions with other main research institutions in the agriculture sector to acquire new knowledge.					
Research officers of our institution regularly visit other research institutions for knowledge seeking activities.(for review meetings, for site visits, etc..,)					
We collect information and knowledge through informal means (e.g. informal discussion, talks with other researchers, through personal relations ...etc.).					
Our institution periodically organizes seminars and conferences to meet other researchers to exchange ideas and acquire new knowledge.					
Knowledge assimilation					
We are very efficient at recognizing new research problems in the agriculture sector.(always address the existing research problems in the sector)					
New knowledge and technology are quickly grasped by our research officers.					
Knowledge transformation					
Our research team regularly considers the impact of new technologies and knowledge on agricultural development.					
Research officers in our institution record and store newly acquired knowledge for future reference.					
Research officers readily share practical experiences with other researchers.					
As a research team, we quickly grasp any opportunities that may arise for our institution from other external knowledge.					
Please indicate number					
How quick your research team are implementing new scientific insight as compared to existing knowledge. **(**Eg: No. of weeks or month , per year/per month etc)					
How often your Research officers meet to discuss implications and possibilities of apply new technologies and knowledge for agriculture development. **(**Eg: No. of weeks or month , per year/per month etc)					
Knowledge exploitation					
Our organization has a clear division of roles and responsibilities as a research institution.					
It is clearly known by our research team how R & D activities within our institution should be performed.					
We constantly consider how to better exploit knowledge gained from other external sources.(regular meetings, scientific discussion., etc)					
Our institution does not have any difficulties in adopting new technologies and knowledge.					
Research officers have a common research culture regarding knowledge/technologies creation and dissemination.					

3. External openness of the Institute

Number of linkages with extra–cluster sources and intensity of linkages. Please indicate the existing linkages of your institutes with following R & D institutes and type of linkage your institutes have made with them

	Institutions	Linkages		Type of linkage			Institutions	Linkages		Type of linkage	
		Yes	No	Technical support	Joint research			Yes	No	Technical support	Joint research
1	Coconut Research Institute					15	Sugarcane Research Institute				
2	Field Crops R & D Institute					16	Rice R & D Institute				
3	Dept. of Export Agriculture					17	Tea Research Institute				
4	Cinnamon & Citronella R & D Institute					18	National Plant Quarantine Centre				
5	Food Research Unit					19	Veterinary Research Institute				
6	Fruit Crops R & D Centre					20	Socio Economic & Planning Centre				
7	HARTI					21	Grain Legumes & Oil crops R & D Centre				
8	HORDI					22	University of *Peradeniya*				
9	Institute of Post-Harvest Technology					23	University of *Ruhuna*				
10	Natural Resources Mgt. Centre					24	*Sabaragamuwa* University of Sri Lanka				
11	National Aquatic Resources R & D Agency					25	*Eastern* University of Sri Lanka				
12	Plant Genetic Resources Centre					26	*Rajarata* University of Sri Lanka				
13	Rubber Research Institute					27	*Wayamba* University of Sri Lanka				
14	Plant Virus Indexing Centre					28	CIC Agri-Business Company				
						29	Serendib Horticultural Technology Centre				
*						*					
*						*					

*Please specify if your institute has any other external linkages

4. Impact of Combinative capabilities on Absorptive capacity of the research institution

Scale items	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
System capabilities					
Our institution has formalized rules and procedures to undertake research activities within institution. (research area, limit of scope and budget, IPR issue)					
We formally communicate relevant information to all research officers in the institution. (information on research grant, training workshop , international conferences and opportunities etc. through public communication channel)					
We have a routinized plan for carrying out research activities, sharing information within and among research institutions. (periodic progress review, symposium, conferences etc.)					
Coordination capabilities					
We ensure participation of all research officers when making institutional decisions on research and all other institutional activities.(when making R & D activity, developing research proposals etc.					
We form task forces or teams to perform research activities. (planning team, project team, monitoring team etc.)					
Socialization capabilities					
Our research team is networked with other internal departments to share knowledge.(joint programme, activities etc., annual gathering)					
Our research team is networked with other external sources to acquire and share knowledge.(annual gathering with other researchers, symposiums etc.)					
We provide a complete orientation programme for newcomers to the institution to apprise them of the organization and its research culture.					
Research team frequently joins a common platform of researchers to share their experiences.					

Chapter 3

The knowledge network of agricultural research Institutes in Sri Lanka: The relevance of network position and absorptive capacity for innovation performances

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Abstract: This chapter explores the relation between knowledge transfer activities and the innovative performance of 29 agricultural R&D institutes in Sri Lanka from a network perspective. Following the literature, it first analyses factors contributing to institutes' embeddedness in knowledge networks. Secondly, it tests whether larger engagements in knowledge transfer activities translate into higher innovation performance.

Based on survey data, the empirical results show that institutes with higher organisational absorptive capacities and scientific publications hold more prominent network positions. They also more frequently acquire external knowledge from publications and professional conferences. Moreover, this empowers them to achieve higher levels of innovation performance.

Keywords: *Absorptive capacity, Agricultural R&D, Centrality measures, Knowledge transfer, Knowledge network*

2.7 Introduction

In the contemporary knowledge-based economy, organisations increasingly rely upon external sources of information to innovate and sustain competitive advantages (Cassiman & Veugelers, 2005; Cohen & Levinthal, 1990; Kostopoulos et al., 2011; Ter Wal & Boschma, 2009). Significant knowledge transfers among organisations occur through mutual learning and inter-organisational cooperation, which stimulates the creation of new knowledge and innovation (Kogut & Zander, 1992; Lester, 2013; Tsai & Ghosal, 1998).

However, many organisations face difficulties in acquiring and benefiting from such external knowledge (Cassiman & Veugelers, 2005; Escribano et al., 2009). This particularly applies to knowledge external to a particular geographic region. In this context, gatekeeper organisations are essential for accessing region-external knowledge and diffusing this into the regional knowledge network (Giuliani, 2002). Such gatekeepers are usually larger firms or universities (Tom Broekel & Graf, 2012). When lacking large firms, which is frequently the case in developing countries, actors capable of playing the roles of knowledge gatekeepers are public R&D institutes. In many instances, these organisations are explicitly set up to diffuse new knowledge on resources, markets, and technologies to local firms (Inkpen & Tsang, 2005).

While many studies explore the relationship between local knowledge networks and firms' innovation performance in developed countries (Tom Broekel & Boschma, 2012; Owen-Smith & Powell, 2004) or within industry-specific clusters (Ter Wal & Boschma, 2009), we still know little about this relation in 'average' regions in developing countries, i.e. regions that do not enjoy the presence of well-functioning knowledge based institutions. In addition, most attention has been paid to profit-oriented organisations, leaving the roles of non-profit (publicly funded) R&D organisations in knowledge networks in developing countries insufficiently investigated.

The present paper seeks to overcome this research gap by means of an empirical study on the network embeddedness of (public) agricultural R&D institutes in Sri Lanka. It outlines the determinants of their absorptive capacity (ACAP), which is a key factor for their knowledge sourcing, diffusion, and innovation activities (Cohen & Levinthal, 1990; Jansen et al., 2005;

Zahra & George, 2002; Lichtenthaler, 2009). Moreover, it relates their knowledge sourcing characteristics and network embeddedness to their innovation performance.

This paper structures as follows. Section 2 elaborates the theoretical arguments and research hypotheses. Section 3 introduces the empirical data and the specifics of the empirical approach. The main findings are presented in Section 4 and discussed in Section 5, which also concludes the paper.

2.8 Theory

2.8.1 Absorptive capacity, knowledge transfers and innovation performances

The transfer of knowledge from one organisation to another is an essential ingredient of today's innovation processes (Kang & Kang, 2009; Escribano et al., 2008). Knowledge transfer is the process through which one organisation gains access to the experience of another (Argote & Ingram, 2000). It is rarely a one-directional process as typically both the receiving and the sending organisations benefit (Tom Broekel & Boschma, 2012; Kotabe et al., 2003). Crucially, knowledge drawn from other organisations is not simply accessible or ready to be used because mere exposure to external knowledge is not sufficient to internalise it successfully (Escribano et al., 2008).

Organisations vary significantly in their ability to share and absorb knowledge. Whether they are able to be successful in this depends on what is conceptualised as their 'absorptive capacity'.[4] This capacity is defined as an organisation's ability to recognise the value of new information, assimilate knowledge, and apply that knowledge towards a commercial end (Cohen & Levinthal, 1990).

An organisation's absorptive capacity is influenced by a number of factors. According to Lazzeri and Pisano (2014), it is primarily determined by their abilities of knowledge acquisition, assimilation, exploitation, and sharing. These in turn are shaped by the knowledge that organisations have previously absorbed (Cohen & Levinthal, 1990). Accordingly,

[4] Interestingly, an organisation's ability to share and diffuse knowledge is rarely addressed and frequently (implicitly) seen as highly correlated with their absorptive capacity. This view is adopted in the current project.

organisations' absorptive capacities embody existing knowledge, routines of learning and knowledge utilisation, and the general resources necessary to complete these processes (Tsai, 2009, 2001). Consequently, organisations' absorptive capacities are formed through a prolonged process of R&D investments and knowledge accumulation, which makes them to some extent by-products of organisations' R&D activities (Cohen & Levinthal, 1990; Bathelt et al., 2004). As it determines an organisation's ability to learn and utilise knowledge, it is an essential determinant of their innovation performance, which motivates the first hypothesis.
H1: An organisation's absorptive capacity is positively related to its innovation performance.

2.8.2 Differences in the types of knowledge exchange

Accessing external knowledge is not a uniform process. There are various ways of external knowledge sourcing and inter-organisational knowledge transfer, such as informal interaction (Laursen & Salter, 2006); formal R&D collaborations (Pisano, 1990; Shan et al., 1994; Narula, 2004); technology acquisition (Granstrand & Sjölander, 1990; Pyka, 1997), and labour mobility (Breschi & Lissoni, 2001). On important dimension in this context is if the exchange takes place in a formal or an informal manner (Kang & Kang, 2009). Informal interactions build upon social contacts and lack regular meetings. They rather involve mutual trust and individual-based non-economic relations (Hakansson & Johansson, 1992; Gulati, 1995), which require relatively low maintenance costs. Accordingly, organisations are (principally) able to establish and maintain a large number of them. It is therefore argued that informal knowledge sourcing is a valid strategy for accessing a diverse set of knowledge sources (Hakansson & Johansson, 1992).

However, this makes informal knowledge sourcing a double-edged sword. On the one hand, it is comparably cheaper and relatively easier to establish in comparison to formal relations. The latter require some kind of (legal) formal framework to be established and held in operations, which cannot be done without effort. On the other hand, due to their relatively low cost, organisations may make excessive use of informal relations and utilise them to a larger extent than their capacity would dictate given their level of absorptive capacity. For instance, organisations may be over-embedded in social relationships (Broekel, 2012; Uzzi, 1996), which will harm their innovation activities. In support of this, Kang and Kang (2009),

Laursen and Salter (2006), and Uzzi (1996) report an inverted U-shape relationship between the extent of using informal knowledge sourcing and organisations' innovation performances. However, most of the insights into the intensity of information knowledge sharing and innovation performance are obtained in the context of developed countries that are usually characterised by dense, social networks among highly specialised actors. It is argued that in the context of developing countries this is less likely to be the case, as (informal) knowledge networks tend to be less dense and involve a greater heterogeneity of actors and knowledge. The lower density implies that redundant relationships are less likely, as is the likelihood of over-embeddedness. The second hypothesis underlines the positive effects of informal knowledge sourcing in the context of developing countries.

H2: The intensity of informal knowledge sourcing positively impacts an organisation's innovation performance.

As pointed out above, R&D-related knowledge sourcing may not only take place in an informal manner. It may also occur on the basis of formal agreements involving signed contracts and long-lasting established relations (Pyka, 1998). Collaborations based on formal agreement usually involves intensive knowledge and capability sharing realised through frequent organisational interactions (Hansen, 1999). Moreover, these have a clear focus and aim, with well-defined boundaries and content of the interactions. Accordingly, they provide a good foundation for inter-organisational knowledge sharing.

The advantages of formal interactions, however, come at the expense of relatively higher maintenance costs and greater difficulty of establishment. Depending on the quality of formal agreements, these interactions' lack of social embeddedness and trust may induce greater risks of opportunistic behaviour, which may eventually translate into negative effects on innovation (Narula, 2004). Therefore, it is expected that organisations with the highest innovation performance will pursue formal R&D collaboration at an intermediate level (Kang & Kang, 2009). Empirical results for developed countries (Uzzi, 1996) back this argument and there is little to indicate why this may be different in the context of developing countries.

H3: The intensity of engaging in formal R&D collaboration is related to innovation performance in an inverted U-shape.

2.8.3 Inter-organizational knowledge transfers from a network perspective

Organisations vary in their absorptive, economic, and technological capacities, as well as in their openness towards external knowledge, which shapes their abilities to connect to inter- and intra-regional knowledge networks (Cohen & Levinthal, 1990; Giuliani, 2011; Giuliani & Bell, 2005). However, while such capabilities are certainly preferable, organisations may access external knowledge in an indirect fashion to compensate for a lack of direct relations to knowledge sources. This is at the heart of the network perspective. An organisation does not need to have many interactions with other organisations directly, it 'just' needs to be connected to the right organisation that has such access. The 'right' organisation in this context is one that interacts and is willing to pass the knowledge it gathers onto other organisations. Such organisations are referred to as gatekeeper organisations (Giuliani & Bell, 2005), which tend to have comparatively advanced knowledge. Frequently, they are early adopters of technologies. In the context of economic geography and regional science, they are seen as 'bridging enterprises' linking to inter-regional networks (Owen-Smith & Powell, 2004). While these organisations are well equipped to identify and diffuse new information external to the region (Malipiero et al., 2005), their local contacts still require sufficient absorptive capacity to utilise and 'absorb' this knowledge (Schrader, 1991; Broekel & Mueller, 2018). In any case, many regional organisations will be net beneficiaries of knowledge diffusion, i.e. they absorb more than they share. In contrast, some gatekeeper organisations may act as (net) knowledge 'sources'. They share more knowledge than they receive. Some may balance knowledge inflows and outflows. Lastly, some neither offer any knowledge nor do they possess the capacity to acquire and exploit external knowledge. Those firms are likely to be isolated from the knowledge network (Giuliani & Bell, 2005).

Within this (social) network perspective on knowledge diffusion and networks, the functions and roles of organisations are identified based on their positions in the network. Accordingly, organisations are conceptualised as nodes and their interactions (knowledge exchanges) as links. On this basis, their (network) position is argued to reflect their abilities and likelihood of absorbing and sharing knowledge (Tsai, 2001). More precisely, an organisation occupying a *central* position in an inter-organisational knowledge network is more likely to access and share knowledge and information (Broekel & Muller, 2018). Consequently, it has been argued

and empirically shown that the innovative performances of organisations depend on their centrality in knowledge networks (Powell et al., 1995; Boschma & Ter Wal, 2007; Tsai & Ghoshal, 1998). This motivates the fourth hypothesis.

H4: The centrality of an organisation's position in a network is positively related to its innovation performance.

The above highlights that organisations' embeddedness and positions in networks are not independent of their absorptive capacities, but rather the contrary. An organisation's absorptive capacity is likely to moderate the effects of its network position on its innovative performance. While a central network position implies easier access to new information, its impact on innovative performance depends on the extent to which an organisation is actually able to exploit and use this knowledge. According to Tsai (2001), an organisation may be able to acquire new knowledge, but still fail in utilising it for its own innovation activities. For instance, an organisation may hire a highly skilled employee but the lesser education of its other employees may prevent that person from sharing and utilising their knowledge with colleagues. Accordingly, a central network position has to be complemented with sufficient absorptive capacity to be beneficial. According to Hansen (1999), this reflects a 'search-transfer problem'. An organisation lacking absorptive capacity may not be able to utilise and transfer the knowledge it accessed through its network. It follows from this that the more central an organisation in a network and the broader its knowledge-source base, the higher the requirements for its absorptive capacity to absorb, transfer, diffuse, and crucially utilise such knowledge. Moreover, it can be expected that absorptive capacity is a requirement to obtain a favourable network position in the first place.

H5: An organisation's network centrality is more positively related to its innovation performance when it is complemented by high absorptive capacity.

The five hypotheses will be empirically assessed with an empirical study on the network of agricultural R&D institutes in Sri Lanka, which is presented in the following. Existing research is still largely focused on developed countries. There, possibilities to interact formally are much easier than in developing countries. Moreover, organisations can rely on long-term

well-established contacts and networks, which are usually absent or less frequent in developing countries. Moreover, the overall levels of absorptive capacity are higher in developed countries, which is less constraining of the number of network relations and knowledge sharing activities. Lastly, the primary focus of existing research is on profit-oriented organisations. In developing countries, these rarely act as gatekeepers or primary absorbers. This analysis therefore contributes to and extends this literature by putting the research lens on non-profit R&D organisations in a developing country.

2.9 Empirical data

This empirical investigation is based on data collected on agricultural R&D institutes in Sri Lanka. There are 36 agricultural R&D institutes in Sri Lanka, including public, private, and university-related institutes. They are similar in their general orientation on agriculture-related research but differ somewhat in their specialisation into thematic fields. Of the 36, 29 were interviewed using a semi-structured questionnaire. The other seven institutes did not wish to be approached.

Top representative of each institute's research teams and of the administrative body (chairman, director, or head of the institute) were interviewed. In addition to the questionnaire, internal records and annual reports were evaluated to provide insights into their innovation performance, R&D contracts, and R&D collaboration activities.

2.9.1 The agricultural research sector in Sri Lanka

The agricultural research system of Sri Lanka has dramatically developed over the last century. A former British colony, Sri Lanka has experienced major development initiatives adopted by British governors. In fact, most contemporary science and technology policies as well as agricultural research policies were originally designed during the colonial period. Currently, the national agricultural research system in Sri Lanka consists of 16 main research institutions and organisations, which are associated to five different ministries. Table 3.9 provides an overview of the institutes. It also indicates which have been interviewed. Figure 3.1 visualises the geographical distribution of the R&D institutes considered in the present study.

In general, the agricultural research sector can be roughly divided into the two main sectors: crop and livestock farming, whereby crop cultivation plays a bigger role in the Sri Lankan economy. The livestock sector in Sri Lanka is less developed and mainly consists of dairy farming and the poultry industry. Crop cultivation includes the plantation sector and the smallholder peasant sector. The plantation sector concentrates on tea, rubber, and coconut cultivation. The smallholder peasant sector is more strongly focused on paddy and other field crops such as vegetables, fruits, spices, etc. The forestry sector is also included in agricultural sector due to the heavy dependency of the rural population.

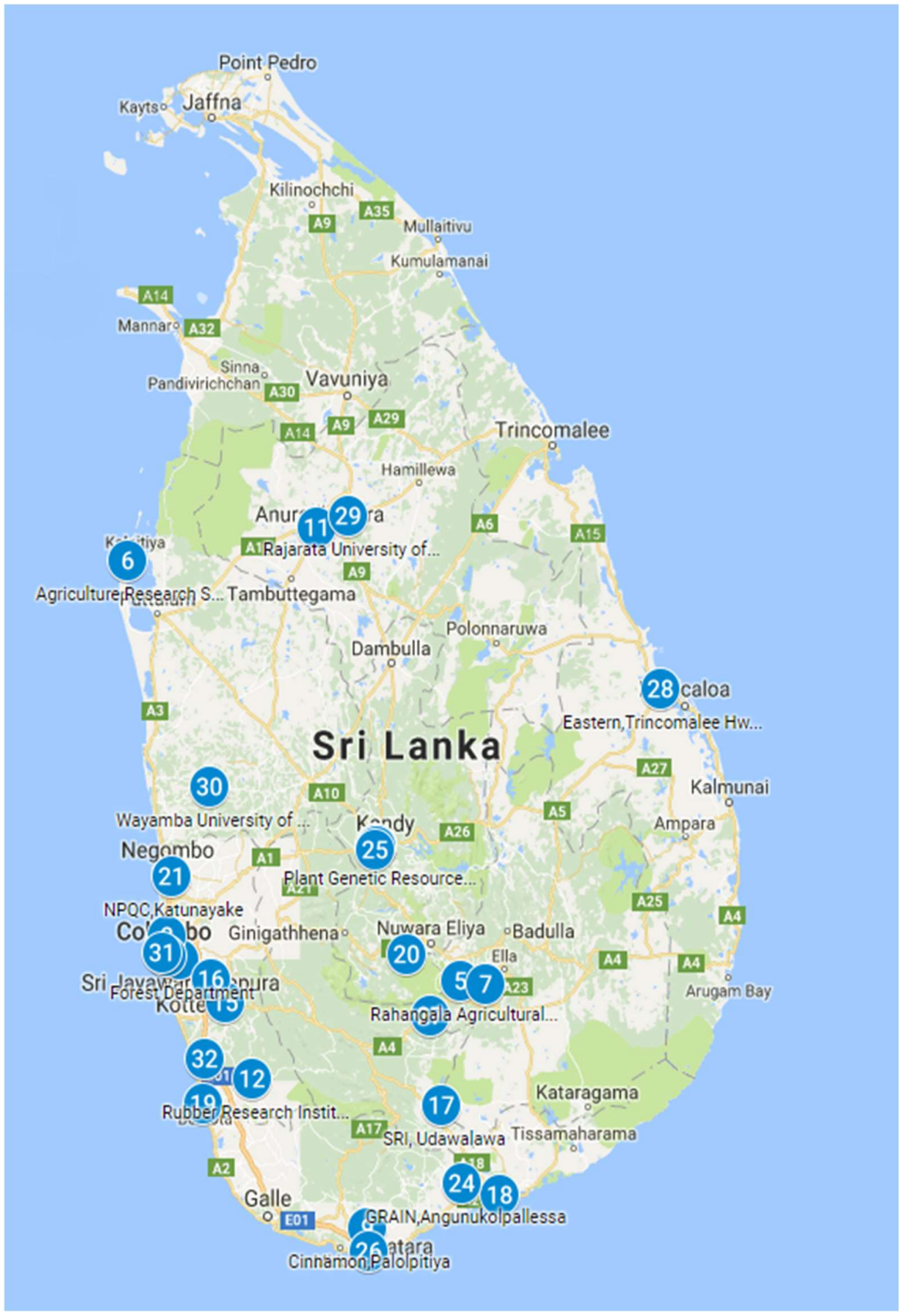

Figure 0:1 : Sample distribution of Agricultural R&D institutes in Sri Lanka

Source: Author own figure using Google map, (2017)

2.9.2 Empirical variables

The questionnaire collected information on institutes' sources of knowledge and interactions with each other. The major knowledge sources were defined after intensive informal discussions and using a pre-defined list of potential sources with respondents being asked to rank the sources according to the frequency they relied upon them. In the end, six knowledge sources were differentiated, of which the relative importance across all interviewed institutes are shown in Figure 3.2 (mean importance, measured on a scale from one to six, with six being most important). All data refers to the time period 2015–2016.

The figure highlights that interactions with other R&D institutes are only the fourth most important source of knowledge, with conferences, journals, and forums or meetings perceived of as being more relevant. Accordingly, knowledge sharing among institutes is not the most important mechanism of knowledge diffusion in this context. However, the differences are marginal and should not be overemphasised.

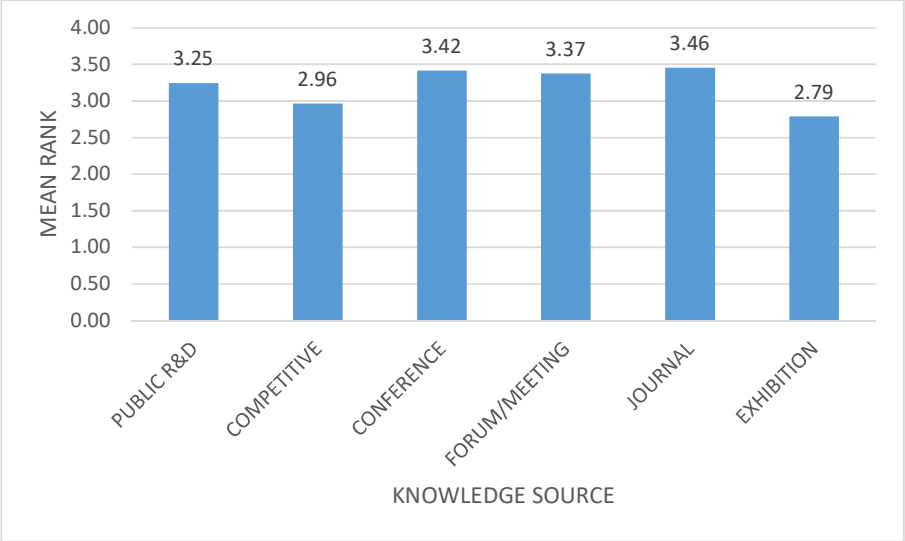

Figure 0:2 : Importance of external knowledge sources

Source: Author's own data, 2017

For the empirical analysis, a number of variables allow for exploring the relevance of knowledge and its sourcing and diffusion on institutes' innovation performance in a quantitative empirical setting.

Innovation performance: Institutes' innovation performance is approximated through the number of publications (PUBL) published by their employees and the number of patents (PATS) granted to them in the years 2015 and 2016. The numbers are obtained from the organisations' internal records. It is generally argued that publications are a better indicator of an institute's contribution to basic research, while patents indicate stronger application-oriented research (Laursen & Salter, 2006; Ahuja & Katila, 2001). The two numbers are used as dependent variables in the models used to identify factors shaping organisations' innovation performance.

Knowledge sourcing: There are various ways to source external knowledge such as information transfers from informal network (Laursen & Salter, 2006), R&D collaborations (Pisano, 1990; Brockhoff, 1992; Shan et al., 1994), and technology acquisition (Granstrand & Sjolander, 1990). Two types of external knowledge sourcing are identified: information transfer based on informal network sourcing and from formal R&D collaboration. The first is captured by the variable INFORM, which represents the sum of the importance levels assigned to six external information sources from which knowledge is acquired without formal agreements. These sources include all agricultural R&D institutes (A), all other R&D institutes that provide knowledge free of charge (B), conferences and seminars (C), annual meetings (D), journals (E), and exhibitions (F). Each of these elements is measured on a five-point scale ranging from no use (1) to strong use (5). Accordingly, the variable has a minimum value of six and a maximum of 30. In contrast to the alternative approach of taking the average across the six sources, the sum creates a single index combining the quantity of sources used and their relative importance.

Formal information sourcing is approximated by the variable COLLAB, which is the sum of the importance (scale from 1–5) assigned to the three most important formal partners in collaborations, including similar R&D institutes, private R&D institutes, and universities. The variable varies between three and 15.

The subsequent measure captures the institutes' absorptive capacity, focusing on the main dimensions of absorptive capacity (acquisition, assimilation, transformation, exploitation) as defined by Zahra and George (2005) and Szulanski (1996). Each of these dimensions is represented by multiple items measured on a five-point agree/disagree (Likert) scale. Four

items approximate the efforts invested into knowledge acquisition. Two items represent assimilation activities. Six items capture knowledge transformation. The latter assess the extent to which the strategies of the institute are able to facilitate the recognition opportunities and possibilities of new external knowledge (Zahra & George, 2002). An additional set of five items assesses the extent to which organisations are able to exploit new external knowledge. All these items are listed in detailed questionnaire in Annex 2E. For each of these dimensions, the average over each associated item is estimated and subsequently summed to obtain the final variable ACAP.[5]

Given the interest in each institute's embeddedness in the knowledge network of R&D institutes, two measures are approximated for this. To obtain information on knowledge sourcing activities among R&D institutes respondents were asked, 'Which organisation provides or shares new knowledge when your organisation seeks technical advice, and which organisation has a relationship with your organisation through a joint or collaborative project?' A list of all agriculture R&D institutes was provided in the questionnaire (see Annex 2.E), allowing respondents to simply select their answers from the list (rooster-recall method). The obtained information is binary, implying that a binary directed network can be constructed.

[5] Given the limited number of observations, more sophisticated empirical methods are not employed at this stage.

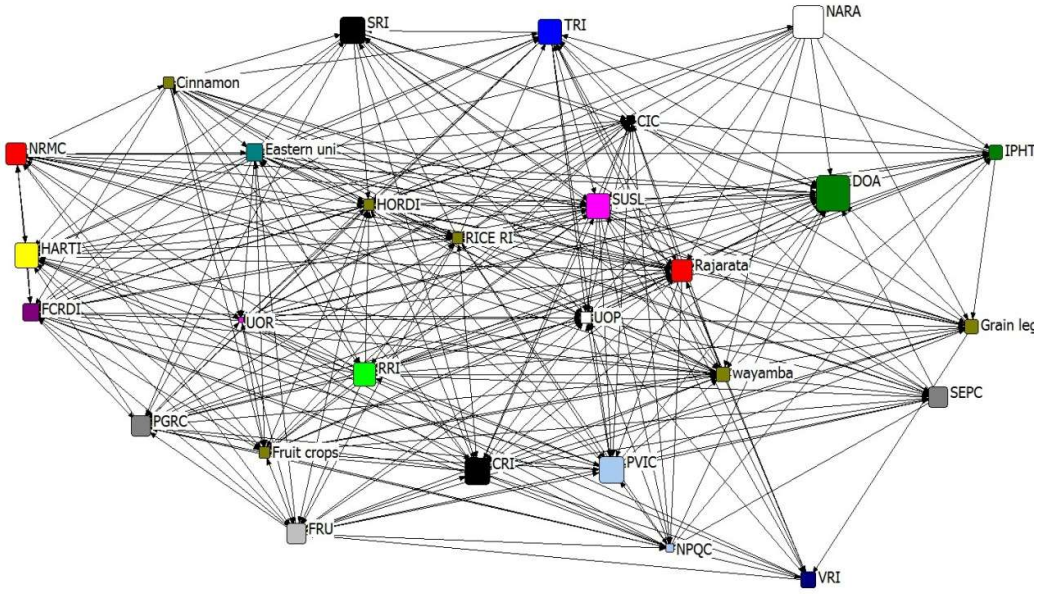

Figure 0:3 : Knowledge network of agricultural R&D institutes in Sri Lanka

Source: Author's own data, 2017

Figure 3.3 illustrates the resulting network.[6] The plot shows a very dense network of linkages among research institutes in Sri Lanka. More precisely, the density of the network is very high, with a value of 0.45, suggesting that 45% of all potential linkages in the network are realised. Density provides an indication of the speed at which knowledge may diffuse among the institutes. Accordingly, knowledge is most likely intensively and quickly shared among institutes. Nevertheless, significant differences in institutes' embeddedness into the network are apparent. To quantify these, nodes' centrality become the focus. Specifically, the degree and betweenness centrality measures defined by Freeman (1979) are relied upon to assess the centrality of institutes in the knowledge network. Given that the obtained network is a directed (binary) network, it is possible to estimate the in-degree (INDEGREE), out-degree (OUTDEGREE), and betweenness (BETWEENNESS) centrality. Out-degree refers to the total number of links originating from a node (being asked for knowledge), i.e. for how many institutes it serves as valuable knowledge source. In contrast, a large number of incoming links (asking for knowledge) translates into a high in-degree value and corresponds to the institute

[6] The size of the node denotes the absorptive capacity of each research institute.

intensively sourcing knowledge from others. In addition to the two versions of degree centrality, the measure of betweenness centrality is also considered. It indicates the importance of an organisation for the overall diffusion of knowledge in the network. It is defined as the number of shortest paths passing through a particular node.

The analyses also include the size of the organisation. Organisations with large numbers of employees tend to have more resources to invest in the production of innovations. The variable EMPLOYMENT is considered accordingly. An alternative indicator is employed for organisations' size: the number of departments (DEPARTMENTS). However, and in particular when being simultaneously considered with EMPLOYMENT, it may also be interpreted as an indication of specialisation, whereby smaller values indicate greater thematic focus.

Table 3.1 summarises the mean values, standard deviations, and correlations for all variables considered.

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8
1	IN-DEGREE	12.61	5.391	1							
2	OUT-DEGREE	12.96	5.467	0.620**	1						
3	BETWENNESS	14.42	15.93	0.032	0.067	1					
4	ACAP	2.93	0.289	-0.137	-0.170	0.405*	1				
5	EMPLOYMENT	27.21	25.43	0.168	0.187	-0.224	-0.131	1			
6	DEPARTMENT	5.38	2.796	-0.162	-0.198	0.218	0.288	0.190	1		
7	PUBL	47.36	91.82	0.344	0.410	-0.183	-0.235	0.888*	0.008	1	
8	PATS	0.86	1.715	0.194	0.193	-0.270	-0.263	0.554	-0.047	0.516**	1

*Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 0:1 : Descriptive statistics of measured variables

Source: Author's own data, 2017

2.9.3 Employed regression analysis

While there are only 29 observations, multivariate regression techniques are applied to test the hypotheses. As the dependent variables that approximate the organisations' innovation success (publications and patents) are count data, Poisson regression is used. Given the low

number of observations, multiple models with varying sets of explanatory variables are estimated.

2.10. Research findings

2.10.1. Institutes' network embeddedness

Before looking at the determinants of research institutes' innovation performance, it is informative to explore their embeddedness into the inter-institute knowledge network. For this, it is firstly explored to what extent organisations' absorptive capacity relates to their position (centrality) in the network. More precisely, a non-parametric correlation test is run between the levels of institutes' absorptive capacities and their centralities. The results are reported in Table 3.2.

Surprisingly, a significant correlation is not found for the measures of degree centrality. In contrast, the relation between absorptive capacity and betweenness centrality is positively significant. This suggests that absorptive capacity positively influences the chances of institutes holding a valuable position in the network, i.e. a position that makes them prone to know about and absorb the information diffused therein (Burt, 1992). The findings of this study contrast with those of Gilsing et al. (2008) that show network centrality to be negatively associated with absorptive capacity. These differences might be because the prior authors' (Gilsing et al., 2008) findings were based on the chemical industry in a developed country and using a larger sample. Accordingly, the network does not only differ structurally from the one observed here (low vs. high density) but also the surrounding technical and institutional framework are substantially distinct.

	INDEGREE	OUTDEGREE	BETWEENNESS
ACAP	-0.090(0.512)	-0.155(0.258)	0.336 (0.013**)

**Significant at the 0.05 level; significant value is in parenthesis

Table 0:2 :The relationship between centrality indexes and organizational ACAP (Kendal tau_b correlation coefficient)

Source: Author's own data, 2017

It is of further interest to explore institutes' heterogeneity with respect to the two types of degree centrality measures, as these provide insights into the role institutes play in the network. In general, when network links represent positive aspects such as collaboration, in-degree is often interpreted as a form of popularity, and out-degree as gregariousness (Srinivas & Velusamy, 2015). This study follows the interpretation given by Giuliani and Bell (2005) relating in- and out-degree differences to organisations' cognitive positions in the network. According to the authors, in-degree centrality measures the extent to which technical knowledge is acquired by or transferred to a firm from other local firms. Out-degree centrality measures the extent to which technical knowledge originates from a firm to be used by other local firms. Therefore, in the context of the present paper, the ratio between in-degree (D_{in}) and out-degree (D_{out}) gives insights into the cognitive position of R&D institutes. That is, the ratio indicates the importance of nodes as a knowledge source, absorber, exchanger, or isolate. The ratio between in-degree (D_{in}) and out-degree (D_{out}) centrality CI is defined as:

$$CI = \frac{D_{in}}{D_{out}}$$

A value of CI > 1 implies an institute is a net 'absorber' of knowledge in the network. A measurement of CI < 1 suggests an organisation is primarily a 'source' of knowledge, and CI=1 means that the organisation functions as an 'exchanger'. In cases where D_{in} and D_{out} equal zero, the organisation is an isolate because it does not engage in any knowledge exchange.

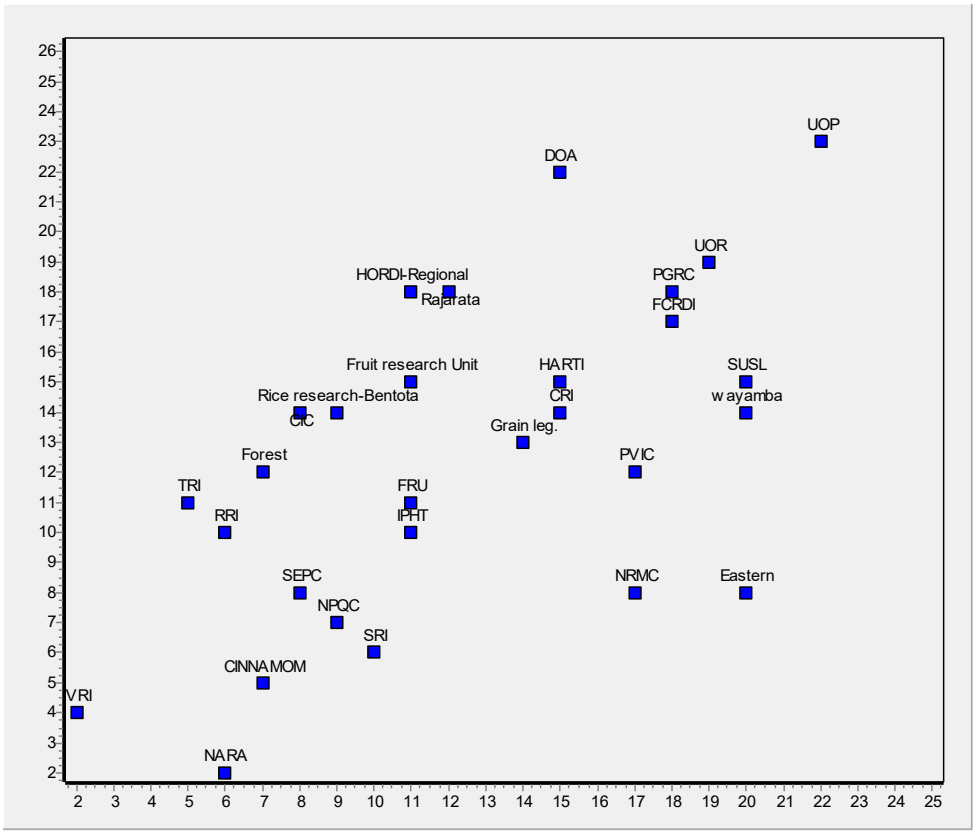

Figure 0:4 Out-degree and in-degree centrality measure of each R&D institute

Source: Author's own data, 2017

In-degree/ Out-degree Centrality Index (CI)	Net Absorbers	Net Sources	Mutual Exchangers	Isolated Firms
CI> 1		FOREST, DOA, RRI, HORDI, FCRDI, Food Research unit, Rice research, TRI, VRI, UOP, CIC, Rajarata University		CI=0 NARA, NRMC, Eastern University
	CRI, CINNAMON, IPHT, PVIC, SRI, NPQC, Grain legumes, SUSL, Wayamba University			
CI=1			PGRC,FRU, HARTI, SEPC, UOR	

Table 0:3 Roles in the agricultural knowledge network

Source: Author's own data, 2017

Figure 3.4 visualises the relationship between the two centrality measures and highlights the great variation between the two, which is in line with previous research in other contexts (Giuliani, 2011; Giuliani & Bell 2005; Bell & Giuliani, 2007; Morrison, 2008; Lee & Kim, 2001). Accordingly, research institutes play very distinctive roles in this knowledge network. Figure 3.4 reveals that R&D institutes related to universities in Sri Lanka (University of Peradeniya, University of Ruhuna, and Rajarata University) have comparatively higher in-degree than out-degree values. In contrast, most of the specialised research institutes (TRI, RRI, CRI, etc.) show average in-degree and out-degree centralities. To make these insights more accessible, the figure is translated into a table, assigning roles to the 29 institutes in the knowledge network. Table 3.3 highlights that the majority of R&D institutes in Sri Lanka (41 percent) act as 'net sources' by providing more knowledge to other institutes than what they receive. This does not come as a surprise, as it is the purpose of these institutes to create and diffuse knowledge. Primary examples of such net sources are the Rubber Research Institute (RRI), Tea Research Institute (TRI), Veterinary Research Institute (VRI), and Rice Research Institute (IRRI), which are also the main research institutes conducting crop specific research. CIC is one of the major private agricultural research institutes. It is strongly engaged in research and training programmes for farmers, which justifies its role as a net source in this network.

The Coconut Research Institute (CRI), Cinnamon Research Institute, Institutes of Post-Harvest Technology, Plant Virus Index Centre, and Grain Legume Research Institute focus their activities on less important crops in Sri Lanka. They frequently exploit external knowledge from other research institutes, rather than conducting their own research. Sabaragamuwa University and Wayamba University are emerging agricultural universities in Sri Lanka and due to their recent growth are still highly dependent on other R&D institutes. Consequently, these institutes and universities are identified as primary knowledge absorbers.

A number of isolates are identified, including the Natural Resource Management Centre, The National Aquatic Resources Research and Development Agency (NARA), and Eastern University. All of these work in very specific research areas, implying a rather large cognitive distance from the other institutes and hence a lack of interaction possibilities within Sri Lanka. For this reason, they appear as (nationally) isolated nodes in the network.

Apart from degree centrality, betweenness centrality measures institutes' relevance for the overall network, i.e. their role in connecting the national agricultural knowledge system. Following the definition of Giuliani and Bell (2005) of betweenness as measure of the degree of cognitive interconnectedness, it is used to quantify the propensity of an institute to be in-between other institutes' knowledge relations. Table 3.4 depicts the R&D institutes with the highest betweenness centrality. The Postgraduate Institute of Agriculture (PGIA) is the main public R&D institute in Sri Lanka, which conducts multidisciplinary research on agriculture. Almost all research institutes refer to PGIA as important in their knowledge exchange activities since it acts as a knowledge hub and, according to this analysis, it also functions as a primary connecting agent in this network. FOREST, NARA, and NRMA basically research specific themes in collaboration with other research institutes and projects, which translates into high degrees of interconnectedness. This implies that collaborative projects with other research institutes enhance the internal capacity of the research organisation while improving network connectivity.

R&D institute	OUT-DEGREE	IN-DEGREE	BETWENNESS
PGIA	18	18	74.14
FOREST	7	12	53.88
NARA	6	2	37.51
NRMC	17	8	36.55
CRI	15	14	32.7
DOA	15	22	28.9
HORDI	11	18	21.33
CINNAMON	7	5	20.44

Table 0:4 Top institutes with high Betweenness centrality

Source: Author's own data, 2017

2.10.2. Determinants of innovation performance

While the previous subsections give insights into the context of inter-organisational knowledge sourcing in the agricultural research sector in Sri Lanka, the following turn towards the question of whehter the identified differences relate to these institutes' innovation performance.

Table 3.5 reports the results of the Poisson regression models relating knowledge sourcing activities and an institute's size to innovation performance. The estimations are split between those using patents and those using publications as a dependent variable. Model 1 serves as baseline, containing only the control variables EMPLOYMENT and DEPARTMENTS. As expected, the first becomes positively significant, indicating that larger organisations generally show higher levels of innovation output. This holds for the innovation performance in terms of basic research, i.e. the number of publications (PUBLICATIONS) and – for the case of applied research – with patents approximating innovative output (PATENTS). The second control for an institute's size, the number of departments (DEPARTMENTS), shows more complex behaviour. While it is negatively significant in the case of publications, it is positively significant for patents. The latter is clearly in line with an interpretation in terms of size – larger institutes tend to have more departments and are also more innovative. In contrast, greater numbers of publications seem to correlate to a smaller number of departments. As pointed out above, this may be an expression of specialisation.

Specifically, smaller numbers of departments are likely to correspond to greater thematic focus and specialisation, which is frequently assumed to positively influence innovation performance (Damanpour, 1991). According to the results, this effect seems to be of relevance at the basic level (publications) but not for applied research (patents).

Square Model	Model 1				Model 2			
Dep. Variable	**PUBL**		**PAT**		**PUBL**		**PAT**	
Indep. Variable	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
EMPLOYMENT	0.041**	0.001	0.021**	0.057	0.040**	0.002	0.016**	0.006
DEPARTMENT	-0.101**	0.018	0.248**	0.768	-0.095**	0.018	-0.094**	0.080
ACAP					0.205**	0.085	-1.267	0.705
Log. Likelihood	-397.88		31.58		-394.89		-29.83	
Chi-square	2429.89**		29.66**		2435.86**		33.17**	

Note: p*<0.1; p**<0.05; p***<0.01

Table 0:5 : Poisson regression, explaining relation of ACAP and innovation performances

Source: Author's own data, 2017

Model 2 tests the relationship between organisations' ACAP and their innovation performance, which was hypothesised to be positive (H1). This is confirmed by the results. As expected, organisations' ACAP is significantly positive, which indicates that organisations with higher ACAP generally show higher levels of innovation output. This holds for the innovation performance in terms of the number of publications (PUBL). A non-significant coefficient is obtained for applied research output (PAT). Consequently, in this context other factors are more decisive for innovative success.

Models 3 and 4 test the importance of informal and formal knowledge sourcing for R&D institutes' innovation performance. Interestingly, in these models ACAP is characterised by a significant negative coefficient in the case of PUBL.

Square Model	Model 3				Model 4			
Dep. Variable	**PUB**		**PAT**		**PUBL**		**PAT**	
Indep. Variable	**Coeff.**	**S.E**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
INFORM	0.023	0.022	-0.046	0.139	2.072**	0.2249	3.510**	1.487
COLLAB	-0.013	0.032	-0.058	0.255	0.893	0.4354	0.057	3.256
$INFORM^2$					-0.052	0.0053	-0.102**	0.039
$COLLAB^2$					-0.050	0.0022	-0.015	0.167
EMPLOYMENT	0.039**	0.002	0.022	0.012	0.047**	0.0024	0.067**	0.026
DEPARTMENT	-0.084**	0.021	0.270**	0.114	-0.056**	0.0225	0.177	0.126
ACAP	-0.220**	0.086	-1.115	0.796	-0.413**	0.081	-1.026	0.704
Log. Likelihood	-394.3		29.64		-334.9		-23.01	
Chi-square	2436.9**		33.56**		2555.83		46.818	

Note: *p<0.1; **p<0.05; ***p<0.01

Table 0:6 : Poisson regression, explaining relation of knowledge sourcing with innovation performances

Source: Author's own data, 2017

This is rather counterintuitive and seems to relate to the inclusion of the collaboration based variables. Accordingly, when controlling for collaboration intensity, ACAP is rather negative. Put differently, ACAP is only positive when translated into actual external knowledge sourcing (asking for knowledge). High ACAP without engagement in external interaction rather seems to be a waste of resources, which reduces innovation performance.

In contrast to hypothesis 2 (**H2**), organisations' formal knowledge sourcing does not significantly relate to their innovative performance. Potentially, it is the greater heterogeneity of knowledge sources and the non-strategic behaviour in this context that prevents these activities from helping organisations to be innovative. Further, R&D organisations might rather depend on informal reliable knowledge sources than on a formal knowledge base for innovative activities. For instance, Silva and Broekel (2019) found that R&D institutes in Sri Lanka strongly rely on formal knowledge sharing platforms for knowledge acquisition and assimilation.

In light of hypothesis 3 (**H3**), which suggests an inverted U-shape relationship between formal collaboration intensity and organisations' innovation performances, COLLAB is included in a

linear and squared fashion. However, the results suggest a rejection of this hypothesis. Both variables' coefficients remain insignificant. An exception is the squared INFORM variable, which becomes significantly negative. This fits the idea of negative effects related to over-embeddedness, i.e. organisations that are strongly engaged in social relations may experience harm from this practice. Over-embeddedness or lock-in effects limit the openness and flexibility of organisations in the context of external knowledge sources (Van Staveren & Knorringa, 2007; Bærenholdt, & Aarsæther, 2002), which in turn will harm their ability to generate novelty (T. Broekel, 2012; Uzzi, 1996).

Summarising the results for hypotheses **H2** and **H3**, it seems to be the case that the differentiation between formal and informal knowledge sourcing is of little relevance for the observed variances in R&D institutes' innovation performance. This contrasts findings for developing countries.

Next, the question is considered whether a more prominent position in the inter-institute knowledge network helps in innovation activities (models 5 and 6) in Table 3.7. In model 5, in-degree obtains a negative significant coefficient when innovation performance is measured by publications while out-degree centrality becomes significantly positive. This implies that knowledge obtained from other research organisations cannot be used for innovation performances while they are sharing their knowledge through publications of the research organisations. In model 6, betweenness centrality shows a significantly negative relationship with innovation performance measured by both publications and patents. Accordingly, hypothesis 4 (**H4**) has to be rejected. It is expected that institutes with higher betweenness centrality will have more control over the network and receive better access to information. However, according to the empirical results, this does not translate into superior innovation performance. Rather the contrary seems to hold. This finding does not only conflict with these predictions, but also most of the existing literature (see Gilsing et al., 2008). The underlying reasons can only be speculated. Most likely, it is betweenness centrality's positive correlation with ACAP that hides this effect.

Square Model	Model 5				Model 6			
Dep. Variable	**PUBL**		**PAT**		**PUBL**		**PAT**	
Indep. Variable	**Coeff.**	**S.E**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
EMPLOYMENT	.037**	.0012	.015**	.0068	.039**	.0010	.010	.0076
DEPARTMENT	-.056**	.0190	.342**	.1022	-.081**	.0176	.370**	.1018
OUTDEGREE	.094**	.0087	.108	.0649				
INDEGREE	-.055**	.0075	-.044	.0541				
BETWEENNESS					-.012**	.0023	-.148**	.0687
Log. Likelihood	-337.74		-29.93		-381.88		-24.62	
Chi-square	2550.17		32.97		2461.89		43.55	

Note: *p<0.1; **p<0.05; ***p<0.01

Table 0:7 : Poisson regression, explaining centrality of an organization's position relation to innovation performances

Source: Author's own data, 2017

The finding also contrasts the visual inspection of the network plot. Figures 3.5 and 3.6 illustrate the network with the number of publications and number of patents being used to weight the size of the nodes. It suggests that the most central nodes are somewhat more active in innovation activities. However, other factors, like their size, are controlled for in the regression analysis, and appear to be responsible for this impression.

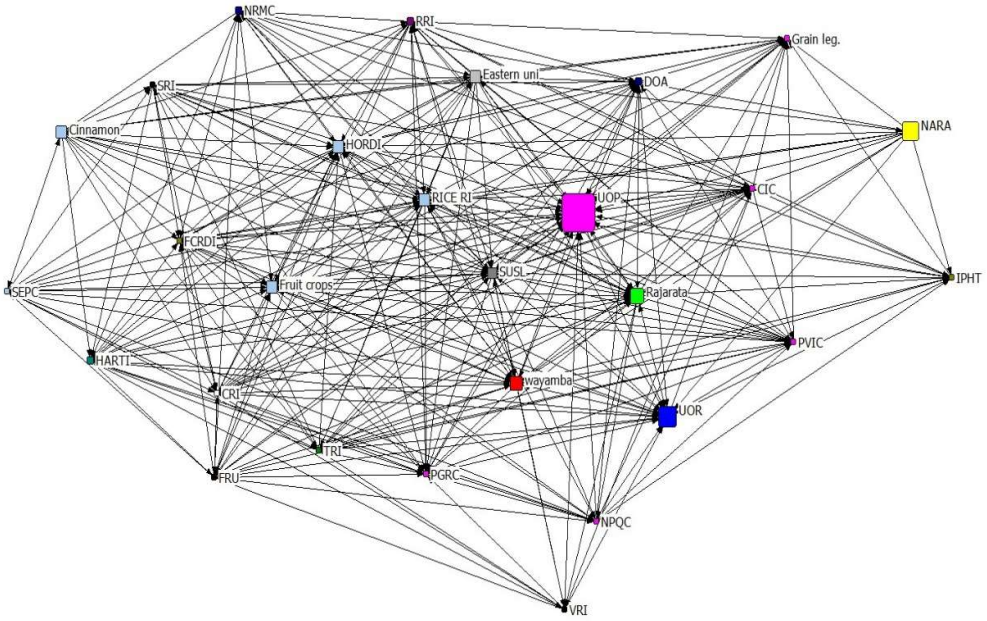

Figure 0:5 : Innovative performance of R&D institutes based on number of publications

Source: Author's own data, 2017

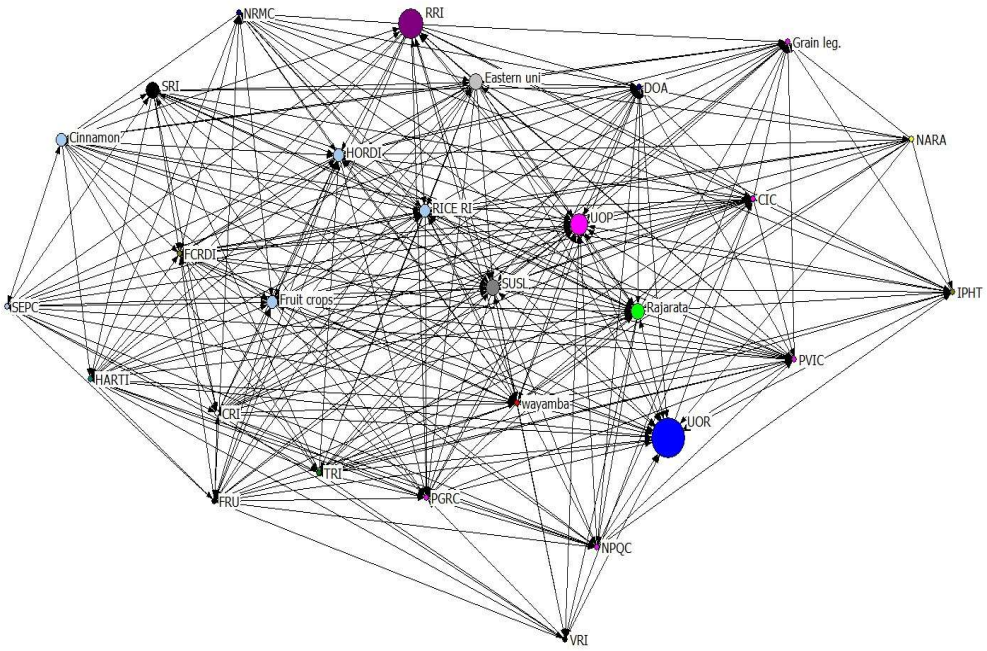

Figure 0:6 : Innovative performance of R&D institutes based on number of patents

Source: Author's own data, 2017

The final models 7, 8, and 9 test the interaction (multiplication) of ACAP with in-degree (model 7), ACAP with out-degree (model 8), and ACAP with betweenness (model 9) to further explore the relationship between ACAP and network centrality. The according results are presented in Table 3.8. In model 7, interaction effect of ACAP with INDEGREE and BETWEENNESS centrality becomes significantly positive when innovative performance is measured by publications. Accordingly, institutes with higher in-degree centrality that are also characterised by higher ACAP seem to benefit from this and are able to realise higher levels of innovation performance. However, these findings have to be seen in light of the negative main effects of INDEGREE, BETWEENNESS, and ACAP. These support the previous interpretation that any positive effects of network positions and ACAP are conditional on each other. That is, ACAP and network position require each other to contribute to innovation processes. Just one is insufficient and potentially represents a waste of efforts, translating into negative effects for innovation performance.

In contrast, ACAP's interaction with OUTDEGREE obtains a high negative value with the according main effects being positive. Accordingly, both are characterised by a rather substitutive relationship, i.e. organisations with lower levels of ACAP tend to be more frequently asked by others and vice versa. This is a somewhat counterintuitive finding. It suggests that institutes are assessing others' ACAP incorrectly and frequently approach those with low ACAP, i.e. those that are unlikely to offer valuable solutions. This might be caused by information asymmetries, which are likely to emerge in the context of developing countries. In other words, it corresponds to a network failure showing as relations formed between actors with a suboptimal fit. This surely demands more research attention in the future.

Nevertheless, hypothesis 5 (**H5**) can be accepted to some extent, as there is a positive relationship of in-degree and betweenness with innovation performance, which is, however, conditional on sufficient levels of ACAP.

Square Model	Model 7				Model 8				Model 9			
Dep. Variable	**PUBL**		**PAT**		**PUBL**		**PAT**		**PUBL**		**PAT**	
Indep. Variable	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
EMPLOYEMENT	.045**	.0021	.011	.0133	.027**	.0017	.007	.0123	.038**	.0011	.011	.0083
DEPARTMENT	-.091**	.0178	.286**	.0813	-.122**	.0223	.307**	.0961	-.088**	.0185	.383**	.1049
ACAP	-1.366**	.3927	-.181	2.4473	4.201**	.5718	.852	3.487	-.284	.1678	.122	1.2010
INDEGREE	-.276**	.0860	.262	.5444								
OUTDEGREE					.872**	.1180	.444	.7332				
BETWEENNESS									-.154**	.0351	-.441	.5695
ACAP*INDEGREE	.091**	.0277	-.089	.1795								
ACAP*OUTDEGREE					-.269**	.0388	-.137	.2490				
ACAP*BETWEENNESS									.043**	.0108	.089	.1757
Log. Likelihood	-389.20		-29.68		-331.44		-29.32		-371.31		-24.39	
Chi-square	2447.24**		33.46*		2562.77**		34.19**		2483.04**		44.02**	

Note: *p<0.1; **p<0.05; ***p<0.01

Table 0:8 : Poisson regression, explaining relation of external knowledge source and innovation performances

Source: Author's own data, 2017

2.11 Discussion and Conclusion

In recent years, few issues have received more attention than the importance of knowledge sourcing for firms' innovative success (Clausen, 2013; Kang & Kang, 2009; Tsai, 2001). However, what has been less explored in general, and with respect to the situation in developing countries in particular, is the relevance of knowledge sourcing of (public) R&D institutes and its relevance for their innovation activities. The present chapter sought to fill this gap by studying knowledge sourcing of agricultural R&D institutes in Sri Lanka. The analysis relies on primary data collection, differentiates between formal and informal knowledge relations, utilises a network perspective, and considers basic and applied research outcomes.

The findings indicate that larger institutes tend to be more active in innovation processes. Interestingly, more specialised institutes perform better in terms of application-oriented research (patenting), while more diverse institutes seem to have an advantage in basic research (publications). Potentially, this mirrors the greater need for diverse knowledge for basic research. In contrast, applied research appears to benefit from a focused approach. This surely deserves more research in the future.

The findings with respect to knowledge sourcing are rather inconclusive. Most variables remain insignificant, suggesting that knowledge sourcing is not a crucial determinant of R&D institutes' innovation activities. This may have two explanations. Firstly, and this will be discussed below in further detail, the empirical set-up has a number of limitations that are likely to cause these results. Secondly, most of the existing research confirming a positive relationship between knowledge sourcing and an organisation's innovation performance has been conducted in the context of developed countries and with a focus on profit-oriented firms. The institutes studied in this paper are located in a developing country. Potentially, other aspects are more relevant for their success (access to funding, relations with customers and ministries, knowledge sourcing from abroad) than knowledge relations among them. The empirical findings in this study support this view with the analysed research institutes naming conferences and scientific journals as more important for obtaining knowledge than their relations with other institutes.

The analysis also reveals that the studied knowledge network is very dense and hence, knowledge seems to be able to quickly diffuse throughout it. This suggests that it less likely to be a limiting factor on institutes' research activities, which fits the observation that in Sri Lanka innovations (publications, patents) are not the primary objective of public R&D institutes. Rather their aim is to diffuse knowledge that has either been invented internally or externally. Consequently, their knowledge sourcing practices are geared to successfully acquire and diffuse knowledge as opposed to utilising this for innovative projects. Future research is also advised to look at this issue. Nevertheless, the results confirm the relevance of the network of knowledge relations among research institutes for these institutes' innovation activities in Sri Lanka, showing that generally higher levels of network embeddedness help these institutes to generate (basic) research outcomes. However, this is conditional on their ability to absorb and utilise this knowledge, i.e. their absorptive capacity. Interestingly, it also indicates a network failure: institutes with relatively lower levels of ACAP (when controlled for size) are more frequently utilised as knowledge sources than those with higher levels. In contrast, those institutes with higher abilities to absorb and share knowledge seem to be less popular sources. This suggests the existence of information asymmetries and a potential for policy intervention.

There are a number of (empirical) shortcomings that need to be mentioned and that put the findings of this study into perspective. Firstly, representatives from only 29 institutes were interviewed, implying that the analysis suffers from a small sample size. More resourceful approaches in the future might be able to collect a greater quantity of data, which will help for the identification of statistically significant relations. Secondly, the empirical analysis is cross-sectional in nature and hence restricted from a methodological point of view. In particular, it does not consider the issue of potential endogeneity. For instance, it seems reasonable to assume that well-performing R&D institutes are prone to hold more central positions in the network than those that are less successful. Future research is advised to make use of longitudinal or panel data to empirically approach this issue. Thirdly, information was collected on whether two R&D research institutes interact with each other with respect to knowledge sharing, but not the type of knowledge that is sourced from their contacts. However, Fornahl et al. (2011) show that it matters with whom organisations interact and

what type of knowledge they can access through this contact. Accordingly, it does not matter so much that institutes interact with each other, but really that they interact with the right institutes.

Given these limitations, no major policy changes are recommended. However, what seems crucial is that R&D institutes in Sri Lanka maintain or even expand their access to conferences and scientific journals, which seem to be important knowledge sources. Moreover, research institutions need to provide sufficient training facilities to their research officers for improving their scientific knowledge.

Annex 3.A

Governing Ministry/Department	R & D Institutes
Ministry of Agriculture	Council for Agricultural Research Policy (CARP),
	Department of Agriculture (DOA)
	Department of Animal Production and Health (DAPH)
	Department of Export Agriculture (DEA)
	Hector Kobbakaduwa Agrarian Research & Training Institute (HKARTI)
	Post-Harvest Technology Institute (PHTI)
Ministry of Plantation industries	Coconut Research Institute (CRI), ,
	Rubber Research Institute (RRI)
	Tea Research Institute (TRI)
	Sugarcane Research Institute (SRI).
Ministry of Fisheries and Aquatic Resource	National Aquatic Resources Research & development Agency (NARA)
	National Aquaculture Development Authority (NAQDA)
Ministry of Environment and renewable energy	Forest department
Ministry of Higher Education	Postgraduate Institute of Agriculture (PGIA)
	University of Peradeniya (UOP),
	University of Ruhuna (UOR),
	Sabaragamuwa University of Sri Lanka (SUSL)
	UwaWellassa University (UWU)
	Wayamba University of Sri Lanka (WUSL)
	University of Jaffna (UOJ)
	Rajarata University of Sri Lanka (RUSL)
	Eastern University of Sri Lanka (EUSL)
Department of Agriculture	Rice research and Development Institute (RRDI)
	Horticulture Research & Development Institute (HORDI)
	Natural Resource Management Center (NRMC)
	Field Crop Research & Development Institute (FCRDI)
	Fruit Crop R & D Centre (FCRDC)
	Food Research Unit (FRU)
	Horticultural R & D institute (HORDI)
	Plant Genetic Resources Centre (PGRC)
	Plant virus Indexing Centre (PVIC)
	National Plant Quarantine Centre (NPQC)
	Veterinary Research Institute (VRI)
	Grain Legumes & Oil crop R & D Centre (GLORDC)
	National Cinnamon R & T institute (NCRTI)
	Seed Certification and Plant Protection Center (SCPPC)
	Seed and Planting Material Development Center (SPMDC)
	Socio- Economic and Planting Center (SEPC)
	Extension and Training Center (ETC)
Private organizations	CIC, Heyles (small scale)

Table 3:9 : R & D institutes in Sri Lanka

Chapter 4

The effect of the motivation-ability-opportunity(MAO) framework on the ACAP of the individual AIs

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Abstract: Agricultural extension services are designed to enable the diffusion of knowledge about farm technology. This process is motivated by the idea of information flowing from agricultural researchers to extension officers (agricultural instructors, or AIs) and from there to farmers. In this setting, AIs act as bridges: their capacity to absorb and diffuse knowledge is crucial for the effectiveness of the entire knowledge dissemination system.

This chapter examines the extent to which AIs' capabilities to identify, assimilate, utilise, and share knowledge are shaped by their motivations, abilities, and opportunities (MOA). Interviews with 72 AIs in the Southern province of Sri Lanka show that their abilities and opportunities contribute to their development of four dimensions of individual ACAP. In contrast, motivation does not seem to be of relevance in this context.

Keywords: *Absorptive capacity, Extension, Knowledge management, MOA framework*

4.1. Introduction

Identifying, selecting, and absorbing useful knowledge from the environment as well as integrating it into concrete applications are key abilities of any organisation for sustaining competitiveness in the long run (Volberda et al., 2010). These abilities are commonly summarised as organisations' absorptive capacity (Cohen & Levinthal, 1990). The idea of absorptive capacity has been proven highly useful for better understanding knowledge transfer within and among organisations (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; van den Bosch et al., 1999; Zahra & George, 2002). Not surprisingly, the concept has therefore found its way into multiple disciplines (Lane & Lubatkin, 1998; Schilling, 1998; Fosfuri & Tribo, 2005; Teece et al., 1997; Eisenhardt & Martin, 2000).

Crucial to organisations' absorptive capacity are individuals and their ability to absorb and learn new knowledge from external sources. Individuals are the primary actors in knowledge creation and key repositories of knowledge (Foss, 2007; Grant, 1996; Felin & Hesterly, 2007). Lane et al. argue that organisational competitive advantages depend on individuals' specific abilities to 'scan the knowledge environment, bring the knowledge into the firm, and exploit the knowledge in products, processes, and services' (2006, 854). Accordingly, organisations' absorptive capacities build on its employees' skills and abilities to acquire, assimilate, transform, and exploit new knowledge (Löwik, 2013). However, these competencies are not uniform across different tasks given the specialisation of most individuals. In addition, it is widely acknowledged that an individual's motivation is crucial in this context (Argote & Ingram, 2000; Minbaeva & Michailova, 2004; Quigley et al., 2007; Osterloh & Frey, 2000).

Despite the vast amount of research done on ACAP, few studies address this individual dimension, particularly the role of motivational factors. Hence, little is known about how individuals at the heart of an organisation's absorptive capacity differ in terms of their abilities and what motivational factors are crucial in this context. Moreover, how do these factors contribute to the development of these capabilities?

The present chapter seeks to close some of these gaps with an empirical study on AIs in agricultural advisory services. These individuals are a key bridge between farmers, research institutes, agricultural schools, agri-business, and other actors (Faure et al., 2012). They are

particularly essential for the adoption of new technologies by farmers. That is, the officers support farmers to form sound opinions and make well-informed decisions by communicating and providing them with necessary information (van den Ban & Hawkins, 1996). Importantly, the officers are also responsible for transmitting feedback from the farmers back to the research system (Rogers, 2003). In other words, for farmers, extension officers play the role of 'technological gatekeepers'.

This study follows Ter Wal et al. (2011) by focusing on individuals' efforts in identifying, assimilating, and utilising external knowledge, adapted to the context of non-profit organisations and AIs. This allows for the identification of factors that impact individual-level ACAP development with respect to different dimensions. This chapter is structured as follows. Section 2 introduces the theoretical background and Section 3 the empirical approach. In Section 4, the results will be presented. The discussion and conclusion are reviewed in Section 5.

4.2. Theoretical background and hypothesis

4.2.1. ACAP and the role of the individual in knowledge transfer processes

Originally, Cohen and Levinthal (1990) identify absorptive capacity as the forefront of the organisational learning. Later, Lane and Lubatkin (1998) and Ter Wal et al. (2011) redefine individual ACAP by more strongly emphasising the identification, assimilation, and utilisation of knowledge to meet commercial ends. Absorptive capacity has been discussed in a wide range of contexts (Lane et al., 2001; Volberda et al., 2010; Tsai, 2001; Zahra & George, 2002). In particular, absorptive capacity has been shown to play a vital role when it comes to knowledge management in general and knowledge transfer processes in particular (Argote et al., 2003; Henderson & Cockburn, 1995; Lane et al., 2006; Szulanski, 1996; Tsai, 2003). Notably, absorptive capacity can be divided into four dimensions (Löwik, 2013): acquisition, assimilation, transformation, and exploitation.

The identification and subsequent acquisition of external knowledge is generally accepted as the first building block of ACAP (Cohen & Levinthal, 1990; Lane et al., 2006; Zahra & George, 2002). Exploring and identifying potentially useful external knowledge is fundamentally a

search process requiring specific efforts of individuals. That is, individuals must invest in the exploration, monitoring, and scanning of a wide range of information and knowledge of external sources. This is not happening automatically as shown by Kogut and Zander (1992). The authors observe that scientists more frequently disseminate knowledge from internal sources than from external sources because of the lesser efforts involved. Individuals require sufficient levels of technical knowledge for successful knowledge acquisition (Todorova & Durisin, 2007). Simultaneously, it is vital that they possess entrepreneurial abilities to identify and seize opportunities to access external knowledge (Löwik, 2013).

Another dimension of individual ACAP is knowledge transformation. Generally, to capture external knowledge, individuals have to assimilate external knowledge. Ter Wal et al. (2011) introduce two main mechanisms in this context. Firstly, individuals need to transform external knowledge such that they are able to convey it to their own organisations. This involves adapting the knowledge in terms of the organisation's native language and culture. It implies making the acquired knowledge understandable and transferable to other members (Löwik, 2013) as well as actually sharing it. At the individual level, this can involve the creation of new ideas individually or in collaboration with others (Löwik, 2013). As a consequence of the knowledge transformation process, organisational procedures, manuals, and databases have to be adapted frequently, which commonly requires collaboration and group activities (Löwik, 2013). Accordingly, besides technological knowledge, individuals need to develop social skills to be successful in knowledge transformation processes.

Closely related and frequently overlapping is the utilisation and exploitation of new knowledge, which is therefore another important dimension of individual ACAP (D. Minbaeva et al., 2003). Once external knowledge has been assimilated into an organisation's internal knowledge base, it needs to be utilised in innovation processes for its benefits to unfold. Knowledge exploitation includes applying the new knowledge and integrating it into work routines (Löwik, 2013). In this context, Tsai (2001) emphasises the need for internal ownership of external knowledge as a requirement for its potential internal application. More precisely, the utilisation of external knowledge demands someone who is passionate about the technology and who is willing to shepherd it through internal decision-making procedures

(Boschma & Ter Wal, 2007). For instance, R&D scientists who pursue the utilisation of external knowledge usually show a commitment to external ideas as if they are their own.

In addition to individual commitment, skills, and willingness, knowledge utilisation and exploitation involves the sharing of knowledge among colleagues and its diffusion across wider organisational boundaries (Jansen et al., 2011). As noted earlier, individuals need to have sufficient interpretation and communication, as well as leadership and teamwork skills. An adequate organisational environment for such kind of activities is also helpful for the facilitation of these processes. Nevertheless, and notwithstanding the importance of collaboration and group work, significant parts of knowledge utilisation are an 'individual action' (Coleman, 1990; Lane & Lubatkin, 1998).

The MOA framework

From the above, it becomes clear that individuals in general and their individual ACAP in particular are at the heart of an organisation's absorptive capacity (Chang et al., 2012). A systematic approach to these individual factors is the motivation-opportunity-ability (MOA) framework developed by MacInnis et al. (1991), Minbaeva & Michailova, (2004), MacInnis & Jaworski (1989), MacInnis et al. (1991), and Minbaeva et al. (2003). The MOA framework has been demonstrated to be a coherent and rigorous theory that helps in explaining variations in behaviours, actions, and performances in the context of knowledge management at the individual level (Change et al., 2012). It emphasises the simultaneous relevance of abilities, motivations, and opportunities in the creation, preservation, and transfer of knowledge (Agrote et al., 2003). Accordingly, motivations, abilities, and opportunities are three interrelated but distinct antecedents of absorptive capacity (Siemsen et al., 2008). Based on this, hypotheses can be derived on how motivation, ability, and opportunity influence an individual to perform specific activities in extension services that contribute to the development of individual and organisational absorptive capacity.

In the context of knowledge transfer, *ability* refers to human attributes such as prior achievements, skills, attitudes, and experiences that enable an individual to learn new knowledge (Argote et al., 2003; Yildiz et al., 2019; Bos-Nehles, 2013; Argote et al., 2003). MacInnis and Jaworski (1989) observe that limited intelligence and education as well as lack

of experience are factors limiting information processing and learning. It is also widely accepted that prior knowledge is the key for further knowledge absorption as it increases creativity and triggers associations between hitherto unconnected chunks of information (Cohen & Levinthal, 1990; Kim, 2001; Minbaeva et al., 2003). Or, as Cohen and Levinthal put it, 'the ability to assimilate information is a function of the richness of the pre-existing knowledge structure' (1990, 131). Yildiz et al. (2019) identify ability as an antecedent factor of absorptive capacity that can contribute to individuals' learning performances. Accordingly, a positive relationship between ability and absorptive capacity is expected, which is captured by the first hypothesis.

H1: Individual ability is positively associated with individuals' development of ACAP with respect to knowledge recognition, assimilation, utilisation, and transformation.

Another decisive factor in this context is *motivation*. The crucial role of motivation has been widely acknowledged in the literature (Argote & Ingram, 2000; Argote et al., 2003; Quigley et al., 2007; Szulanski, 1996, 2000). According to Yildiz et al. (2019), the level of willingness of an individual to augment their skills to recognise, assimilate, and exploit new external knowledge depends on their type of work motivation. Two types of motivation are typically considered in this context: intrinsic and extrinsic motivation (Osterloh et al., 2002). Intrinsically motivated people work for self-satisfaction and the sheer joy of it, whereby they have little expectations of immediate rewards (Osterloh & Frey, 2000; Ryan & Deci, 2000). Intrinsic motivation is directed towards a self-defined goal or to oblige the personal and social norms for their own sake (Osterloh et al., 2002). According to Amabile (1997), a highly intrinsically motivated person is likely to acquire necessary skills in the target domain from various external sources by applying great effort. In line with this, Vansteenkiste et al. (2004) show that intrinsically motivated individuals tend to score highly in terms of learning performance. According to Rigolizzo and Amabile (2015), individuals need to be intrinsically motivated to learn how to explore new ideas and assimilate external knowledge even if the outcomes of such efforts are not immediate or visible. Therefore, the intrinsic motivation of employees plays a critical role, particularly in organisations that depend on their employees' capabilities to create new

knowledge and share tacit knowledge with others (Osterloh & Frey, 2000; Cabrera et al., 2006).

In contrast to intrinsic motivation, extrinsic motivation is salient when the activity leads to material rewards and explicit recognition (Gagne & Deci, 2005). Individuals are extrinsically motivated to engage in knowledge acquisition and dissemination activities when their needs will be satisfied indirectly, primarily through financial compensation. Consequently, extrinsically motivated employees are more likely to respond to self-imposed pressure or external regulations (Yildiz et al., 2019). This study considers both motivation types together and emphasises the role of motivational factors in the second hypothesis.

H2: Individual (intrinsic and extrinsic) motivation is positively associated with individuals' development of ACAP with respect to recognition, assimilation, utilisation, and transformation.

The third element in the MAO framework is opportunity, which feeds into ACAP (Argote et al., 2003). It refers to environmental and contextual elements that enable knowledge creation, retention, and absorption actions (Siemsen et al., 2008). Following Bos-Nehles et al. (2013), opportunities are conceptualised in terms of individuals' work environments and how their daily work context is shaped. Since this study will focus on agricultural extension officers (AI) who act as bridges between research and farmers, socialisation mechanisms are crucial drivers for the development of AIs' absorptive capacity.

In this context, many studies emphasise the centrality of social proximity between sender and receiver. While social proximity generally facilitates more efficient knowledge transfers, it also increases its likelihood by producing opportunities for further interaction that eventually lay the basis for future knowledge exchange (Lagendijk & Lorentzen, 2007; Broekel & Binder, 2007; Bathelt et al., 2004; Mäkelä et al., 2007; Argote et al., 2003; Boschma, 2005, Fritsch & Monz, 2010). Particularly, trust-based social relationships enable the exchange of tacit knowledge, which is by nature more difficult to communicate (Boschma, 2005; Kirat & Lung, 1999). Notably, social proximity (Henrik et al., 1999) is frequently linked to geographic proximity (Boschma, 2005; Broekel, 2015). For instance, it is broadly accepted that social relations are more likely and more intense when actors are in geographic proximity, as, in

fact, many social linkages are established through co-location (Breschi & Lissoni, 2009). Aware of this, many organisations organise social events to facilitate person-to-person contact (Argote & Ingram, 2000; Minbaeva & Michailova, 2004; Minbaeve et al., 2007). The benefits are confirmed by Bresman et al. (1999), who illustrate that interpersonal communications, such as visits and meetings, are significant facilitators of international knowledge transfers. Accordingly, it is expected that opportunities created through social interaction play a significant role for the individual ACAP of extension officers.

H3: Opportunities created through socialisation are likely to facilitate individuals' development of ACAP with respect to knowledge recognition, assimilation, utilisation, and transformation.

The three hypotheses will be empirically evaluated on the basis of a case study on 72 AIs in the Southern province of Sri Lanka.

4.3. Empirical approach

4.3.1. Case study: agricultural extension officers

Agricultural advisory services are recognised as important elements for improving farm performance. In particular, they are acknowledged as strengthening ties between farmers, research institutes, agricultural schools, agri-business, and other actors (Faure et al., 2012). The subsequent analysis focuses on 'extension' serves, which refers to systems that facilitate the access of farmers, their organisations, and other market actors to knowledge, information, and technologies (Christoplos, 2010). These systems also stimulate interactions with partners in research, education, agri-business, and other relevant institutions. They further assist farms in developing their own technical, organisational, and management skills and practices (Faure et al., 2012).

The literature recognises agricultural extension services as a vital element for the development of the agricultural sector. In developing countries, the major aim of the agricultural extension service is to increase farm production efficiency through the adoption of new technologies. Thereby, the role of an agricultural extension agent is to help farmers

form sound opinions and make good decisions by communicating with them as well as by providing the information they need for technology adoption (van den Ban & Hawkins, 1996). Accordingly, agricultural knowledge transfer processes include the flow of information about innovations from the agricultural extension organisation to the farmers and the transmission of feedback from the farmers to the research stations (Rogers, 2003).

With regard to the role of agricultural extension officers, it is important that they learn from the external environment, share their knowledge, and disseminate information about best practices effectively. Accordingly, their work is conceptualised as a process of knowledge acquisition from external sources (mostly research) with subsequent sharing and disseminating of that knowledge among farmers. This makes them an ideal object for study, as these officers' absorptive capacity is their primary resource in their job and defines their level of success.

To measure individuals' absorptive capacities, this study follows Ter Wal et al. (2011), who propose a new measurement scale, which is here adopted to the context of AIs. Moreover, following Gupta and Govindarajan (2000), absorptive and disseminative capacity are conceptualised as one integrated capacity, which represents individuals' capacities to identify, absorb, and utilise as well as to disseminate their knowledge to others. Consequently, the full range of AIs' activities in the process of knowledge transfer are considered. This includes their efforts to keep aware of novel developments, to access and integrate external knowledge, and to incorporate that knowledge into their knowledge base. Attention is also paid to the identification of external knowledge. For example, AIs constantly monitor research outcomes and new technology. Individual officers, moreover, tend to obtain new knowledge and information through their personal and professional social networks. They translate external knowledge and information into a form that is understandable to local farmers and actively share it with other AIs. In the context of utilisation of external knowledge, AIs need assistance from those farmers named as contacts to overcome the hidebound resistance of older farmers to effectively participate in knowledge dissemination.

The focus group for this study is 88 agricultural instructors (AIs) working in the Southern province of Sri Lanka. The province is one of the most prominent agricultural regions in the country. A structured questionnaire was used, which was pre-tested with a random sample

of ten AIs to enhance the clarity of the questions and to avoid interpretation errors. This resulted in the modification of some questions. Subsequently, another 62 AIs were interviewed who self-selected by responding to individualised email invitations. Since only marginal differences were observed between the answers provided by the ten AIs of the pre-test and the 62 of the final round, responses were combined to obtain the final data set consisting of the responses of 72 AIs.

4.3.2. Empirical variables: dependent variables

The aim of this study is to explain the individual development of AIs' individual ACAP in terms of knowledge acquisition, utilisation, and transfer (Bresman et al., 1999; Minbaeva et al., 2003). Following Minbaeva et al. (2003), the respondents were asked to indicate whether (1) they have tried to obtain information about emerging technologies when interacting with their contacts; (2) they consistently update their knowledge by reading newspapers, magazines, and pamphlets; and (3) they regularly read scientific journal articles, conference papers, patent information, etc. to keep abreast of new knowledge and technology to identify potentially useful knowledge. These three items are measured on a five-point Likert scale ranging from 1 = 'little or no extent' to 5 = 'very large extent'.

The items are condensed by means of a principal component analysis (see Table 4.1). The first component has an eigenvalue greater than one and explains about 57 percent of the variance. This component will serve as the first dependent variable and represents the abilities of AIs in terms of knowledge identification (IDENT). Empirically, it is the weighted average of responses of the three items listed above using the component loadings as weights (Cronbach's alpha = 0.63).

INSERT TABLE 4.1

The second dependent variable approximates the knowledge assimilation process of AIs (ASSIM). To capture this, respondents were asked to indicate their degree of agreement on six items (see Table 4.2). Again, a five-point Likert scale is used and the six items are condensed using a principal component analysis. In contrast to knowledge identification, the variance captured by the first component (ASSIM) is just 44 percent. Accordingly, there is

substantial variance not contained in this variable. Most likely, this is due to the greater number of items entering the analysis. In addition, all other extracted components do not represent thematically consistent variables aggregates. Consequently, and for consistency, this approach is maintained throughout.

INSERT TABLE 4.2

Two further dependent variables are created approximating AI's knowledge utilisation (UTILI) and transformation (TRANS) in an identical fashion. The results are summarised in Tables 4.3 and 4.4. Both variables perform better in terms of variance captured (66 percent and 71 percent, respectively) than the previous two.

INSERT TABLE 4.3 and 4.4

The four dependent variables are related to a set of explanatory variables that represent individual characteristics and motivational factors influencing the development of the individual ACAP of AIs. They are introduced below.

4.3.3. Explanatory variables

The first explanatory variable is the officers' motivation (MOTIV). Motivation considers in particular the motivational process governing individuals' choices as defined by Vroom (1995). To capture both individuals' extrinsic and intrinsic motivation for improving their activities, respondents were asked about their preference for being rewarded with respect to their contribution to managing (new) knowledge: whether they are driven by self-interest or by extrinsic incentives offered by their organisations. The context of the present study, with AIs working for non-profit organisations, led to the expectation that intrinsic would be more important than extrinsic motivation. Nevertheless, three variables were used to measure intrinsic and two variables to approximate extrinsic motivation. The variables include (1) motivation from increments bonuses, (2) motivation from career promotion, and (3) motivation from increasing personal income; and 4) motivation from providing value to the department and 5) motivation obtained from the organisational reputation being increased.

Specifically, AIs' achievements and services were examined with respect to two major policy programmes (FFS and Yaya 2).[7] The corresponding five-point Likert-type scale ranges from 1 = 'little or none' to 5 = 'very large extent'. The variable *individual-motivation* is operationalised as above using the first component of a principal component which captures 67 percent of the variance of the individual variables (Alpha = 0.874).

The second focal variable is the opportunities (OPPORT) that AI have to develop their individual ACAP. Among different types of opportunities put forward in the literature, of particular consideration are socialisation mechanisms that encourage cooperation and facilitate knowledge transfer processes. The variable is constructed on the basis of AIs responding to the following four items (Likert scale ranging from 1 = 'strongly disagree' to 5 = 'strongly agree'): (1) Having frequent meetings and contacts with farmers for the purpose of sharing knowledge; (2) having informal communications and meeting with their colleagues, e.g. during tea breaks, social events, etc.; (3) having a good social (informal) relationships with all the farmers in their area; and (4) whether farmers are seeking frequent consultation for field problems and to obtain information. The aggregation is done by a principal component analysis and the first component, which captures 46 percent of the variance of the individual variables (Alpha= 0.527), is considered.

In addition to motivation and opportunity, the individual abilities of AIs (ABILITY) are measured based on five items. However, principal component analysis shows that only four of these items can be combined into a meaningful component and the analysis is restricted accordingly. The items considered are the responses (on a five-point Likert scale) to questions concerning: (1) to what extent their personal ability enhances their job efficiency and productivity; (2) whether their career development dependents on skills and abilities; (3) to what extent their skills and abilities help in sharing knowledge among colleagues and farmers; and (4) whether their individual abilities support their job satisfaction and performance (see Kianto et al., 2016; Singh & Jain, 2013). The obtained variable ABILITY is internally consistent as Cronbach's alpha is 0.595, and 42 percent of the variance of the individual variables is observed.

[7] A detailed analysis of these programmes and adoption rates are discussed in Silva and Broekel (2019).

4.3.4. Control variables

Four variables control for potential confounders related to the heterogeneity in the sample of AIs that are unrelated to the research question, which may nevertheless have an influence on the development of their absorptive capacities. The first one is the years of experience that AIs have gained in extension service (EXP), which is measured by the number of years the officer has had his post in the extension service in Sri Lanka. The age of AIs is also argued to be an important determinant of their ACAP (Reige, 2009; Ismali & Yusof, 2005; Gumus, 2007). The variable AGE takes this into account.

Moreover, Riege (2009) and Keyes (2008) identify a positive relationship between education level and knowledge sharing behaviour. Consequently, the variable EDU is constructed, which represents the level of AIs' education. This was done by categorising the educational levels of AIs into five categories, considering the four major educational levels of the Sri Lankan educational quality framework: educational qualification with advanced level (A/L), diploma in agriculture (Dip), Bachelor's degree in agriculture (B.Sc.), Master's in agriculture (M.Sc.), and other levels of educational qualifications. Lastly, Hansen and Løvås (2004) report that physical distance impacts the likelihood and efficiency of knowledge sharing in this context. Therefore, the average distance between AIs and the farms for which they are responsible (DIST) is considered.

4.4. Research findings

Given the nature of the data, a cross-section OLS regression is employed. This requires testing its underlying assumptions. Firstly, a test is carried out for the error terms following a normal distribution by means of the Kolmogorov–Smirnov normality test.[8] The test does not support this assumption; however, the violations are rather minor. Moreover, it is known that minor deviations from a normal distribution of the error terms do not tend to bias the results (Li et al., 2012). Accordingly, the OLS model is approved for assessment.

[8] IDENTI (KS=0.383, $p<0.05$), ASSIMI (KS=0.440, $p<0.05$), UTILI (KS=0.333, $p<0.05$), TRANS (KS=0.378, $p<0.05$).

In addition, the data is checked for deviations from linearity. Except for model 4 of knowledge identification, all models are characterised by the presence of linear relationships, as the test statistics are insignificant.[9] With respect of knowledge transformation, significant deviations from linearity are observed for model 3 (p=0.044), while all the others are insignificant. Visual inspections of the original values suggest that the deviations are negligible and primarily driven by few observations with rather large values (see Annex 4A). Some issues are observed with heteroscedasticity. Therefore, the dependent variable is transformed into log values, which fixed these issues.

In addition, potential multi-collinearity of the explanatory variables is tested using the variance inflation factor (VIF) (see also the correlations as reported in Table 4.6). The VIF values of the explanatory variables range between 1.20 and 5.9, indicating that multi-collinearity is not an issue (Tian & Soo, 2014).

INSERT TABLE 4.6

As the individual factors (motivation, ability, opportunity) matter for an AI's development with respect to the different dimensions of individual ACAP, four distinct dependent variables are reviewed for explanation. The results are presented in Table 4.7 with identification being the dependent variable, Table 4.8 for assimilation, Table 4.9 for utilisation, and Table 4.10 for transformation. For each of the dependent variables, four distinct models are estimated, implying that in total 16 regressions have been completed.

The first model (model 1) represents the baseline including only the control variables. In model 2, the variable ABILITY is added as an explanatory variable. Model 3 extends the set of explanatory variables by the variable MOTIV. Finally, model 4 presents the full model including all explanatory variables (control variables, ABILITY, MOTIV, and OPPORT).

The regression analyses do not reveal any significant relationship. In particular, they fail to explain the variance of knowledge identification. Accordingly, no concrete findings can be

[9] IDENT (Model 2), p=0.354; IDENT (Model 3), p=0. 473, IDENT (Model 4), p=0.035; ASSIM (Model 2), p=0.279; ASSIM (Model 3), p=0.123 and ASSIM (Model 4), p=0.422; UTILI (Model 2), p=0.06; UTILI (Model 3), p=0.150; UTILI (Model 4), p=0.488; TRANS (Model 2) p=0.054; TRANS (Model 3), p=0.044, TRANS (Model 4), p=0.380.

reported. For the other dependent variables, some models are acceptable from a statistical perspective. Their findings will be interpreted in the following.

With respect to the control variables, there is a significant statistical relation for DIST, i.e. the distance between farmers and AIs' offices, in the models for assimilation (Table 8). However, the coefficient is significantly positive, which implies that AIs perform better in terms of assimilation the farther their offices are from the farms. This is somewhat counterintuitive, and the data has not illuminated a useful explanation at this point. Consequently, future research needs to dig deeper into this issue.

Concerning the first hypothesis **H1**, individual ability being positively associated to the development of individual ACAP, there is some support for this in terms of knowledge assimilation (Table 4.8) and utilisation (Table 4.9). At least, when not controlling for opportunities (OPPORT), a positive significant coefficient is found for the variable ABILITY. Accordingly, individual abilities matter when it comes to knowledge assimilation and utilisation. The fact that the variable loses its significance when opportunities are considered is somewhat surprising, given the rather moderate correlation between the two (see Table 4.6).

In contrast to ABILITY, there is no significant relationship between the individual levels of motivation (MOTIV) and AIs' development with respect to any dimension of individual ACAP. The according coefficients remain insignificant in all models and specifications. Accordingly, hypothesis **H2** is not supported by the research findings. This is a striking finding because motivation is expected to have a positive impact on the performance of individuals (Ibrahim & Brobbey, 2015; Akcha, 2014; Fomenky, 2015; Shahzadi et al., 2014; Narun & Dip, 2017). Future research needs to explore this in more depth.

The third hypothesis **H3**, emphasises that opportunities matter for the development of individual ACAP. In this case, the findings clearly support this with respect to the knowledge acquisition, assimilation (Table 4.8) and knowledge transformation dimensions (Table 4.10). In the models for knowledge utilisation (Table 4.9), the variable OPPORT remains insignificant. The significant coefficients of the variable are significantly positive, indicating that opportunities are positive for the development of almost all dimensions of individual ACAP.

This finding suggests that providing more opportunities for AIs to socialise with farmers, researchers, and other AIs, can be a way to improve their work.

4.5. Discussion and Conclusion

Due to its importance for innovation and knowledge diffusion, organisational absorptive capacity has been at the forefront of the literature on organisational learning, innovation, and knowledge management (Zahra & George, 2002). Crucially, the absorption of knowledge by organisations is only partly a process at the organisational level; substantial parts of it involve individual learning. Put differently, essential parts of organisational absorptive capacity are the individuals actively involved in knowledge absorption and transfer processes (Cohen & Levinthal, 1990). Amongst others, this implies that the conceptualisation and analysis of ACAP needs to recognise and explicitly consider the individual level.

However, while ACAP has been intensively studied in the literature, most work concentrates at the organisational level, leaving the individual level somewhat underexplored (Volberda et al., 2010). To be more precise, while the role of individuals is frequently emphasised when organisational ACAP is studied, the determinants of individual-level ACAP are widely neglected in the literature so far. This gap motivated the present study, which consequently investigated factors impacting the development and success of individuals in knowledge transfer processes.

The presented study argues that the development of individuals' ACAP can be explained with the so-called MOA framework (Jansen et al., 2005; Hughes et al., 2014; Minbaeva et al., 2003), which therefore represents the study's theoretical basis. That is, it explored to what extent individuals' ACAP is influenced by motivation, opportunity, and ability. Using the case of AIs in Sri Lanka, this framework is utilised to gain a better understanding of how these factors contribute to their performance in terms of transferring knowledge from external sources (e.g. research institutes) to farmers.

The empirical analysis relied on survey data for 72 agricultural instructors. The results show that individuals' abilities do have a positive effect on their absorptive capacities. In particular, abilities significantly contribute to the development of their capacities in terms of knowledge

assimilation and utilisation, which supports the work of Cohen and Levinthal (1990) and Lane et al. (2001). In addition, the results are in line with the work of Zahra and George (2002) that also show ACAP being positively associated to high levels of employees' abilities.

The results further support the work of Argote et al. (2003) that stresses the importance of opportunities in knowledge transfer processes and consequentially in the development of individual ACAP. Opportunities emerging from socialisation processes improve knowledge transfers and thereby help in the development of individual ACAP (see also Hansen et al., 1999). These findings also suggest that socialisation mechanisms positively influence three out of four dimensions of ACAP (identification, assimilation, and transformation). In accordance with Moron (2005), it underlines that a certain degree of (social) closeness to partners is important when engaging in knowledge transfer processes.

In an important point, the results also depart from the existing literature: motivation is not observed as playing a decisive role for any of the dimensions of ACAP. Such is put forward by Zahra and George (2002), who argue and empirically show that the utilisation and transfer dimensions of ACAP are influenced by motivational factors. It is suspected that these authors' results are driven by not differentiating between extrinsic and intrinsic motivation, which features in this study.

Besides its contribution to the existing scientific literature, this study also allows for a couple of important implications. First, it offers insights into how extension organisations can prepare and encourage their instructors to absorb and transfer new knowledge more effectively. For instance, stimulating motivation through rewards systems seems unlikely to work in Sri Lanka. This might be because either AIs are already highly motivated or existing reward schemes do not adequately address their needs. The findings also point to the importance of abilities and opportunities in this context. For example, extension services can be improved by stimulating AIs' interests in generating and seizing opportunities for social interaction. By creating more opportunities for AIs to interact with major stakeholders of the agriculture innovation system, knowledge diffusion within the system is likely to improve. Examples of such opportunities are upgraded communication possibilities, team building, and establishing a culture of shared knowledge.

Another implication of the research findings is that the work of AIs can be improved by increasing their individual abilities in terms of knowledge absorption. Staffing, training, and performance appraisal are potential tools that can be used to achieve this.

However, the findings have to be seen in the light of some limitations, mainly that the empirical analysis builds on information of only 72 AIs in a Southern province of Sri Lanka. Accordingly, it is unclear to what extent local particularities limit the generalisability of the findings, particularly how different cultural backgrounds influence how AIs respond to various organisational factors. Consequently, the research should be repeated in other locations and consider other actors of the agricultural innovation system. Further, this study highlights individual heterogeneity and its effect on the knowledge absorption and transfer process. Therefore, future research should examine how personal traits and other individual-level factors shape knowledge sharing and transfer processes.

Items of knowledge identification/acquisition	Component loading
You always actively try to obtain information about the emerging of new technologies from others when interacting with them	0.522
you update your knowledge everyday by reading newspapers, magazines and pamphlets	0.846
you have regularly read scientific journal articles, conference papers, patent information etc. to keep abreast of new knowledge and technology to determine the knowledge identification process	0.863
Eigenvalue	1.733
Cumulative variance	57.78
Cronbach alpha	0.63

Table 4:1: Items of knowledge identification

Items of knowledge assimilation	Component loading
You work hard to assess the potential value of external knowledge that may be pertinent to the farmers' problems and needs	0.577
You often try to work out how the expertise of external contacts could be used to meet farmers' needs	0.756
You try to get my colleagues interested in new external knowledge and technologies	0.751
You frequently meet my colleagues to exchange ideas and discuss any new knowledge I obtain externally	0.542
You perform a central role in diffusing externally sourced knowledge to farmers and colleagues	0.640
You make every effort to "repackage" external knowledge to make sure it suits the local conditions	0.700
Eigenvalue	2.661
Cumulative variance	44.38
Cronbach alpha	0.724

Table 4:2 : Items of knowledge assimilation

Items of knowledge utilization	Component loading
When any external knowledge appeals to your fields and farmers, you work vigorously to make sure it is improved and made practical for application at the field level	0.815
You put in great effort to minimize any resistance to the adoption of new knowledge and techniques	0.815
Eigenvalue	1.328
Cumulative variance	66. 42
Cronbach alpha	0.490

Table 4:3 : Items of knowledge utilization

Items of knowledge transformation	Component loading
You shared acquired knowledge among the colleagues of extension services	0.759
You transform acquired knowledge to the field level need and effectively share among farmers	0.892
You gained knowledge from knowledge sharing process	0.873
Eigenvalue	2.135
Cumulative variance	71.2
Cronbach alpha	0.791

Table 4:4 : Items of knowledge transformation

Items of AI performances	Component loading
You can claim credit for improving farmers' adoption of new technology as a result of the hard work you did to persuade them	0.734
Farmers in your service area have a good opinion of you due to your honest work	0.851
You have gained your knowledge by participating in a large number of training sessions, conferences and workshops conducted by government and private research institutes	0.695
You have earned the farmers' trust and confidence through your dedication, energetic activities and good decisions made on field issues	0.828
Eigenvalue	2.432
Cumulative variance	60.79
Cronbach alpha	0.774

Table 4:5 : Scale items of measuring AI performances

		Mean	S.d	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1	AGE	35.20	6.95	26.00	57.00	1											
2	EXP	7.81	6.47	1.00	34.00	0.77**	1										
3	EDU	2.47	0.58	1.00	4.00	-0.15	-0.18	1									
4	LOCATION	15.22	8.93	2.50	47.50	-0.06	-0.02	-0.09	1								
5	IDENT	3.90	0.60	2.00	5.00	0.03	0.04	0.02	0.22	1							
6	ASSIMI	4.25	0.46	3.00	5.00	0.01	-0.09	0.07	0.23*	0.38**	1						
7	UTILI	4.29	0.43	3.50	5.00	-0.16	-0.18	-0.10	0.06	0.10	0.43**	1					
8	TRANSF	4.27	0.53	3.00	5.00	0.02	-0.07	-0.06	0.10	0.25*	0.50**	0.49**	1				
9	ACAP	16.81	1.41	13.00	20.00	-0.03	-0.10	0.03	0.16	0.61**	0.72**	0.69**	0.73**	1			
10	ABILITY	3.86	0.51	2.40	5.00	-0.09	-0.09	0.04	-0.14	0.02	0.21	0.23*	0.15	0.19	1		
11	MOTIV	3.21	1.00	1.00	5.00	0.02	-0.03	0.12	-0.02	-0.00	0.00	0.01	-0.05	0.00	0.39**	1	
12	OPPORT	3.90	0.56	2.00	5.00	-0.21	-0.17	0.11	0.12	0.27*	0.30*	0.28*	0.35**	0.42**	0.34**	0.29*	1

Table 4:6 : Descriptive statistics on study variables

	Model 1	Model 2	Model 3	Model 4
Intercept	0.556(0.077)**	0.524(0.107)**	0.523(0.108)**	0.412(0.114)**
AGE	0.000(0.002)	0.000(0.002)	0.000(0.002)	0.001(0.002)
EXP	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.000(0.002)
EDU	-0.004 (0.016)	-0.004 (0.016)	-0.004 (0.016)	-0.007(0.016)
DIST	0.002(0.001)	0.002(0.001)	0.002(0.001)	0.002(0.001)
ABILITY		0.008(0.018)	0.008(0.019)	-0.004(0.020)
MOTIV			-0.001(0.010)	-0.005(0.010)
OPPORT				0.043(0.018)**
Observation	72	72	72	72
Adjusted R^2	-0.001	-0.014	-0.029	0.033
F test	0.978	0.810	0.667	1.350

Note: p*<0.1; p**<0.05; p***<0.01

Table 4:7: OLS regression analysis on knowledge identification

	Model 1	Model 2	Model 3	Model 4
Intercept	0.549(0.046)**	0.457(0.062)**	0.450(0.062)**	0.394(0.066)**
AGE	0.002(0.001)	0.002(0.001)	0.002(0.001)	0.002(0.001)
EXP	-0.002(0.001)	-0.002(0.001)	-0.002(0.001)	-0.002(0.001)
EDU	0.006(0.010)	0.006(0.010)	0.008(0.009)	0.006(0.009)
DIST	0.001(0.001)**	0.001(0.001)**	0.002(0.001)**	0.001(0.001)**
ABILITY		0.022(0.010)**	0.027(0.011)**	0.021(0.011)
MOTIV			-0.007(0.006)	-0.009(0.006)
OPPORT				0.021(0.016)**
Observation	72	72	72	72
Adjusted R^2	0.040	0.088	0.092	0.138
F test	1.74	2.377**	2.206**	2.622**

Note: p*<0.1; p**<0.05; p***<0.01

Table 4:8: OLS regression analysis on knowledge assimilation

	Model 1	Model 2	Model 3	Model 4
Intercept	0.675(0.044)**	0.593(0.059)**	0.589(0.060)**	0.545(0.064)**
AGE	0.000(0.001)	0.000(0.001)	0.000(0.001)	0.000(0.001)
EXP	-0.0011(0.001)	-0.0011(0.001)	-0.0011(0.001)	-0.0011(0.001)
EDU	-0.0106(0.0091)	-0.0106(0.009)	-0.010(0.0091)	-0.0106(0.009)
DIST	0.000(0.001)	0.000(0.001)	0.000(0.001)	0.000(0.001)
ABILITY		0.020(0.010)**	0.022(0.011)**	0.017(0.011)
MOTIV			-0.003(0.005)	-0.005(0.006)
OPPORT				0.017(0.010)
Observation	72	72	72	72
Adjusted R^2	0.000	0.043	0.035	0.064
F test	0.996	1.645**	1.425	1.689

Note: p*<0.1; p**<0.05; p***<0.01

Table 4:9: OLS regression analysis on knowledge utilization

	Model 1	Model 2	Model 3	Model 4
Intercept	0.590(0.056)**	0.518(0.077)**	0.509(0.077)**	0.407(0.079)
AGE	0.002(0.001)	0.002(0.001)	0.002(0.001)	0.003(0.001)
EXP	-0.002(0.002)	-0.002(0.002)	-0.002(0.002)	-0.002(0.001)
EDU	-0.007(0.012)	-0.007(0.012)	-0.005(0.012)	-0.008(0.010)
LOCAT	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.000(0.001)
ABILITY		0.017(0.013)	0.024(0.014)	0.012(0.014)
MOTIV			-0.008(0.007)	-0.012(0.007)
OPPORT				0.039(0.012)**
Observation	72	72	72	72
Adjusted R^2	-0.017	-0.005	0.001	0.126
F test	0.706	0.935	1.013	2.466**

Note: p*<0.1; p**<0.05; p***<0.01

Table 4:10 : OLS regression analysis on knowledge transformation

Annex 4 A

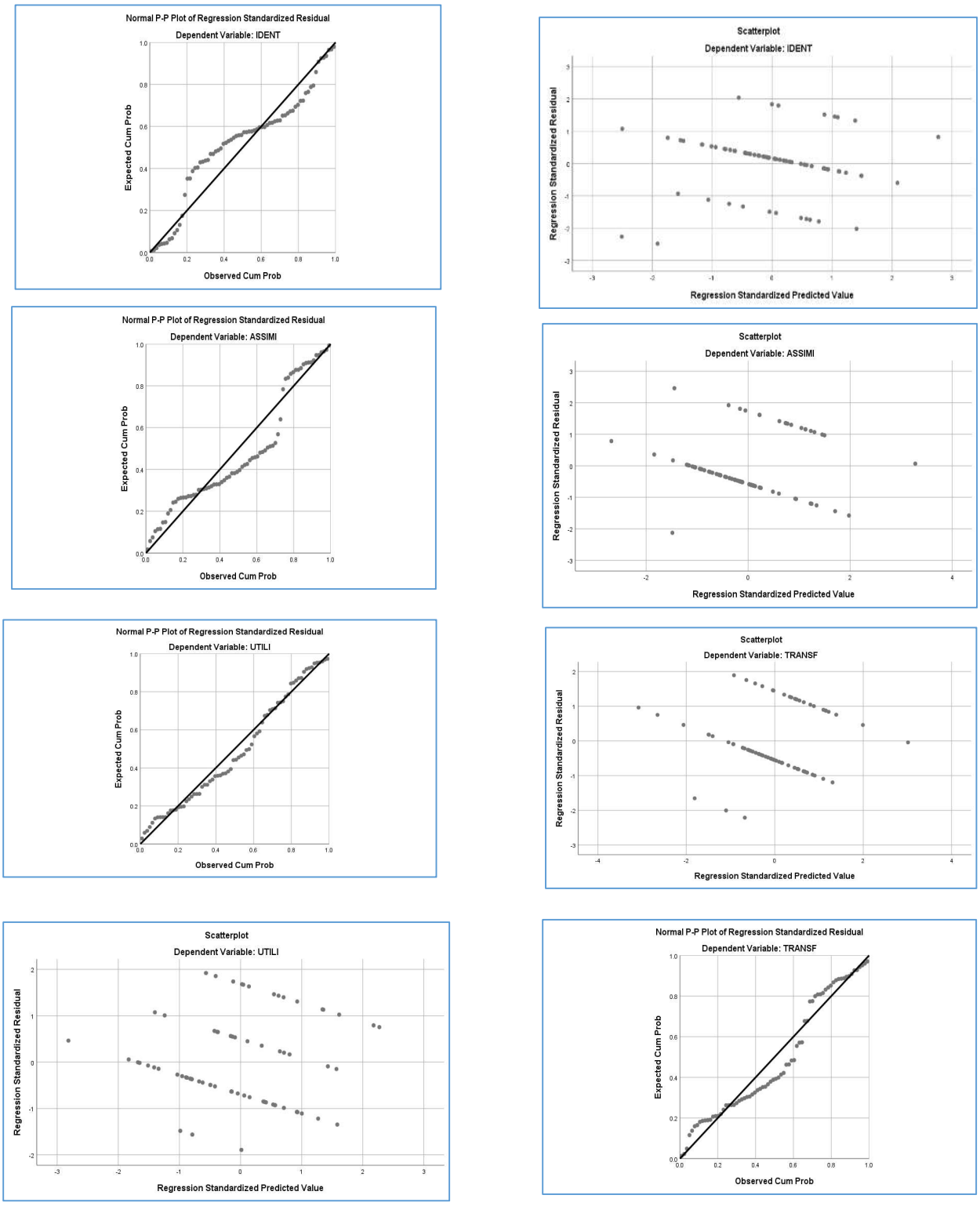

Figure 4:1 : Normality and Heteroscedasticity

Chapter 5

Accessing and using agricultural information and technology – Evidence from paddy farmers in the Hambantota District of Sri Lanka

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Abstract: This chapter explores the access and use of agricultural knowledge and information by paddy farmers in Hambantota district in Sri Lanka. Following the literature, an attempt is made to determine if formal information sharing processes are dominant among paddy farmers. Frequently, farmers receive and share information formally with the agricultural extension officers as they are the most trusted and most accessible information sources. The empirical study shows that the farmer's age and farming experience shows a positive relationship with the adoption of new technologies, while technology adoption behaviour is not significantly affected by the social and demographic factors of farming communities.

Keywords: *Agriculture information, Diffusion, Information sourcing, Technology adoption*

5.1. Introduction

The agricultural sector forms the backbone of the economy in most developing countries. In Sri Lanka, the economy is heavily dependent on agriculture, which accounts for nearly 7 percent of the gross domestic product. This accounts for 24 percent of exports and employs 34 percent of the workforce (Central Bank of Sri Lanka, 2016). Various studies have revealed that there is a positive relationship between an increased flow of knowledge and information and agricultural development (Pipy Fawole, 2008).

Farmers acquire information from multiple sources, including neighbouring farmers, extension agents, social media, etc. It is well known that knowledge about new technologies diffuses primarily through local social networks. For example, farmers share information with other farmers regarding new technology, cultivation, market conditions, and subsidy programmes (Bandiera & Rasul, 2006; Conley & Udry, 2010; Foster & Rosenzweig, 1995; Munshi, 2004; Krishnan & Patnam, 2012).

However, out of the multiple sources of information available to a farmer, whom to approach first for information is determined by many factors. Proximity effect (social, geographical, cultural), cost, and the reliability of information affect the information sharing patterns of farmers (Conley & Udry, 2010; Yamauchi, 2011). Research has shown though that typically farmers in developing countries cite certain farmers in the neighbourhood as their most trusted and reliable source of information (Bandiera & Rasul, 2006); therefore, it is important to understand how links in these social networks are constructed (Magnan et al., 2015).

The present chapter adds to this debate by differentiating between the most frequent information sources and the most useful information sources, a distinction that rarely appears in the literature. Moreover, it takes into consideration farmers' adoption behaviours on new technologies. Some farmers choose to be innovators (first users) while others prefer to be early adopters, late adopters, or non-adopters.

These issues are addressed by means of investigating the information flow and knowledge sharing patterns among paddy farmers in the Hambantota district of Sri Lanka, where concerted

efforts have been made towards the diffusion of agricultural knowledge and technologies. To be more precise, this study concerns whether and how farmers interact with one another in the neighbourhood, with extension workers, and with innovative farmers in their villages. To analyse the information receiving and sharing pattern of the farmers, it considers formal and informal information sharing methods. Typically, sharing information with other farmers in the neighbourhood and innovative farmers in their village is considered an informal information method; information sharing with extension workers (AIs) and agriculture research officers (AOs) is considered a formal information sharing method. Farmers in the study sample were asked to mention their information sharing behaviour with respect to information on new technology.

In contrast to many existing studies analysing the pattern of diffusion of one specific technology, a wide range of paddy technologies introduced by the Department of Agriculture in Sri Lanka are considered. Then it considers the behaviour of a farmer who is confronted with all these different technologies and has to decide which one to choose, or whether to adopt any new technology at all in the first place. This paper is structured as follows. Section 2 elaborates on the theoretical arguments and derives the research hypotheses. Section 3 outlines information on the empirical data and the specifications of the empirical approach. Section 4 presents the main findings, and Section 5 discusses them and concludes the paper.

5.2. Theory

5.2.1. Information sharing and Technology Adoption behavior

Farming is a knowledge intensive industry. Farmers need to obtain and process technical, climatic, marketing, and financial information to manage a farm profitably. For many agriculture-related activities, knowledge is needed. This has become even more important in recent years.

Innovations are governed by adoption and diffusion processes. Diffusion can be interpreted as aggregate (widespread) adoption. As mentioned by Atibioke (2012), a technology is adopted when the decision is made to make full use of a new idea as the best course of action available. Further, the adoption of technology involves a change in the attitude and behaviour of the farmer

from the time they become aware of the technology to the time of its adoption. Therefore, there is a significant time lag between the introduction of a new technology and its adoption by farmers. Adoption behaviours in respect to new technology may be affected by many factors. The vast literature on this topic mentions several factors that influence technology adoption (Chi & Yamada, 2002; Adebiyi & Okunlola, 2013; Adesina & Baidu-Forsen, 1995; Akudugo, 2012).

As in the works of diffusion theories, innovation diffusion has been related to two processes – social interaction and geographic proximity, which are moreover interlinked. This is also true for farmers' knowledge sourcing in developing countries. Farmers in these countries mostly cite other farmers as their most trusted and reliable sources of information, i.e. they rely on their social network for information (Rogers, 2010). Young (2009) and Hogset and Barrett (2010) show that these social networks not only offer specific knowledge, they also impact an individual farmer's behaviour through social learning processes and influence. Muange et al. (2015) highlight imitation and mimicry as crucial learning mechanisms in this respect.

As in developed countries, farmers' social networks in developing countries are strongly shaped by the neighbourhood effect, i.e. geographic proximity (Yamaguchi, 2005; Conley & Udry, 2010; Foster & Rosenzweig, 1995; Munshi, 2004; Besley & Case, 1994). Hence, while farmers evaluate the trustworthiness of their social networks highly, these may not provide the best and most recent knowledge. This knowledge is much more likely to be present in public extension services, formal commodity groups, and a wide array of private providers. Also, public agencies such as the Department of Agriculture's Extension Service, private providers including commercial vendors, non-governmental organisations, and agricultural publications and media offer this type of information. However, this is more difficult to access and may not be easily available to many farmers.

Yet, in most cases, public agriculture organisations are not located in close geographic proximity and few social ties are established between these and the farmers. Hence, the neighbourhood-based social network serves as the most frequent source of knowledge. The inability to access reliable and adequate information, and consistently receiving information in an accurate and timely manner, are still the most challenging issues facing farmers (Just & Zilberman, 2002).

According to Just and Zilberman (2002), farmers appreciate the accuracy and reliability of formal information. However, the authors also recognise informal information as being very timely in most cases, though it may be inaccurate as well as biased.

In addition to farmers' preference for timely and accurate information, there are other factors that may influence technology adoption (Chi & Yamada, 2002; Adebiyi & Okunlola, 2013; Adesina & Baidu-Forsen, 1995; Akudugo, 2012). Some of the factors determining the extent of adoption of technology include the following: attributes of the technology, objective of the farmer, characteristics of the change agent, and the socio-economic, biological, and physical environment in which the technology is introduced. Socio-demographic attributes of farmers such as age, educational attainment, income, family size, tenure status, credit use, value system, and beliefs are positively related to adoption (Sunding et al., 1999). Empirically, Atibioke (2012) finds that certain socio-economic factors such as occupation, gender, and level of education significantly affect the adoption of technologies.

Apart from that, the personalities of extension officers in the area too could influence the farmers' adoption behaviours. Their credibility, good rapport with farmers, and communication ability, acting in combination with effectiveness of the technology transfer mechanism, can affect adoption levels. These may be further affected by the biophysical environment of the farming region, its infrastructure, and the availability of essential resources to the farm, which all can positively influence the farmers' technology adoption decision.

5.2.2. Research questions and hypothesis

Preference for timeliness and accuracy

As pointed out above, farmers may have a preference for obtaining information in a quick and easy way, which usually implies contacting other geographically and socially proximate farmers. Yet, in light of the potential deficits in terms of accuracy and reliability, it is expected that farmers will opt for higher quality of knowledge sources.

H1: Farmers prefer to exchange information through the formal farmer network rather than through informal methods.

Farm size

Farmers with larger holdings are more likely to adopt relatively new innovations due to the benefits conferred by economies of scale: the rate of return on adoption is higher for larger farms. Furthermore, larger farms have relatively greater capacity to bear risks since they have professional management systems within their farms (Diederen et al., 2002). Farm size is one of the first and most widely used parameters on which the empirical adoption literature has focused.

H2: Farmers who have larger farms are more likely to adopt new technologies.

Age of the farmers

On average, older farmers have a lower level of education, which may be correlated with the ability to weigh the pros and cons and make an adoption decision. Schinitky et al. (1992) argue that there is a correlation between age and farm experience. Experienced farmers will rely less on external information, and tend not to be interested in new technologies as their younger counterparts.

H3: The younger the farmer, the more likely they are to adopt new technologies.

Education level

The education level of the Sri Lankan farming community varies from primary school to graduate level. Better educated farmers are more likely to adopt new technologies and, accordingly, education is expected to have a positive effect on the adoption of production technologies (Strauss et al., 1992; Warriner & Moul, 1992). However, some researchers have found education to be an insignificant factor (Saltiel et al., 1994; Clay et al., 1998), or to even negatively correlate with adoption (Gould et al., 1989; Okoye, 1998).

H4: Educated farmers are more likely to adopt new technologies.

Farming experience

Farming experience, which is assumed to become more extensive with age, has shown different results regarding adoption behaviour. Assessments of the role of experience in adoption reveal both positive correlations (Clay et al., 1998) and insignificant ones (Traoré et al., 1998). According to Okoyo (1998), some more experienced farmers are less likely to use new technologies as a result of their past experience and so behave as late adopters. At the same time, other more experienced farmers have recognised the importance of new technologies and thus the probability of their adopting new technologies is comparatively high (Strauss et al., 1992).

H5: More experienced farmers are more likely to adopt new technologies.

Access to extension services

This study experiments with the effect that distance between farmers and the extension office has on inducing farmers to adopt new technologies. Farmers are much more likely to visit the agricultural extension officers and will do so more frequently if the extension office is close to their farms. Further, Sanginga (1995) (as cited in Atibioke, 2012) finds a positive significant relationship between contact with extension services and the adoption of technologies by farmers. Therefore, a new hypothesis analyses the impact that access to extension service has on technology adoption. It is assumed that farmers who lived or worked within a short distance from the extension officers are more likely to adopt new technologies.

H6: Farmers who have easy access to extension services are more likely to adopt new technologies.

5.2.3. Adoption categories of paddy farmers

To test these hypotheses, this study adopts the categorical framework of Rogers (2003) and a similar study design as Diederen et al. (2003). Rogers (2003) has drawn attention to an adoption practice of farmers based on the innovation-decision period, which is the length of time required for the innovation-decision process to be completed. The time that elapses between awareness

– that is, knowledge of an innovation – and the decision made to adopt it by an individual can be measured in days, months, or years.

Based on the availability of information and social influences, farmers adopt new technologies at varying paces, with some doing it promptly while others take time. Rogers (1983) has proposed five main adopter categories on the basis of innovativeness, and the degree to which an individual is quicker in adopting new ideas than other members of a community: innovators, early adopters, early majority, late majority, and laggards. Therefore, this study aims to analyse and compare farmers by placing them in different adopter categories based on their adaptation of innovations that originate in the Department of Agriculture in Sri Lanka. To be more precise, paddy farmers in the selected sample were given a short questionnaire and asked to answer two key questions: (1) whether they have adopted and implemented any important innovation that was introduced by the Department of Agriculture during the last two cultivating seasons, and (2) whether they could indicate their position regarding this innovation in terms of the general diffusion of these innovation in their community. These categories are then statistically related to the factors mentioned above.

5.3. Empirical data

The empirical research is based on data collected from paddy farmers in Hambantota district in Sri Lanka. Ten Divisional Secretariat (DS[10]) areas in Hambantota district of Sri Lanka were selected for the study. These DS areas were purposively selected to represent a dry zone paddy farming community, based on an exploratory discussion held with government agricultural instructors in Hambantota district. Netolpitiya, Vitharandeniya, Udayala, Bandagiriya, Angunukolapelessa, Weeraketiya, Walasmulla, Modarawana, Beliatta, and Katuwana Grama Niladari divisions *(GN*[11]*)* of Hambantota district were chosen due to similar paddy cultivation practices and land extent.

[10] The districts of Sri Lanka are divided into administrative sub-units known as divisional secretariats.
[11] A sub-unit of a divisional secretariat (DS).

Paddy cultivation farmers' registration lists were accessed through the agriculture instructors and they were used as the sampling frame of the study. One hundred (100) paddy farmers were selected for the study with ten farmers representing each GN division.

Two sets of data were collected to capture the sources of agriculture information. Firstly, detailed information was gathered on hypothetical information sources, based on the question, 'To whom would you go for advice if there were any problems with your farming activities?' Secondly, information flows were explored by asking farmers about important paddy cultivation issues. The five issues were the result of a discussion, with the leaders of the farmers' organisation[12] in each GN divisions.

Figure 5:1 : Map of GS divisions of Hambantota District in Sri Lanka

Source: Department of Census and Statistics (2004)

[12] A farmer organisation is a group of farmers with special interests and concerns with developed structure, formal membership, status, and functions for its members and with a set of by-laws and rules.

The first topic for exploration is in what way farmers primarily receive information: through formal or informal communication channels. To be more precise, respondents were asked about their knowledge sharing activities with extension workers, training programmes, etc., (formal channels) and informal interactions such as group discussions and chats with neighbours and friends. The answers were collected with respect to five distinct issues (cultivation problems, new technology, market information, subsidy information, and other).

Meanwhile, farmers tend to access information through different information channels. In this study, four types of information sources were considered. Farmers were questioned about their source of information for the new technologies. According to study findings, AIs are the major information source for farmers. Secondly, farmers also visit their neighbours to gather information (Castella et al., 2006; Lwoga et al., 2011). Adomi et al. (2003) also have found that extension officers were the most important sources of information even though farmers were dissatisfied with the frequency of extension officers' interactions. Apart from that, Bandiera and Rasul (2006) have recorded that farmers in the same group or network often discuss agricultural practices with their network partners. Only one percent of farmers seek out innovative farmers in the community for their information needs in spite of their importance.

Similarly, this study has focused on the most influential actor in the information sharing process among the major providers of information. Though there are many disseminators of information, farmers tend to trust and rely mainly on the most influential source. AIs are the most influential actors (scoring 81 percent) as far as the farmers in Hambantota district are concerned. Secondly, neighbours (at 18 percent) have also assisted farmers in the information and knowledge sharing process.

Lastly, farmers were asked about the factors that influence the knowledge and information sharing pattern with different source of information. Farmers were asked about five main factors that affect their knowledge sharing pattern. The farmers themselves were asked to rank each factor according to their assessment of its importance in the information sharing pattern. According to the study findings, information availability is the most important factor in the

knowledge sharing process, followed by social relationship, and easy access. Distance to AI officer and cultural proximity were the least important factors.

5.4. Empirical approach

It is the study's main objective to assess the relationship between farmers' adoption behaviour and their socio-economic characteristics (age, farming experience, education level, farm size, formal communication channels, and access to extension service), studying a total of about 100 valid observations (farmers). In a first step, farmers are categorised according to the adoption classes developed by Rogers (2003). These were defined on the basis of the time farmers needed to apply a new technology after being introduced to it and being made aware of its benefits. The farmers' perceptions regarding their own attitudes in respect to technology adoption were also considered. Figure 5.2 shows the distribution of farmers across the different categories, which clearly indicate innovators and early adopters as the most dominant categories. Due to the limited number of observations and this very skewed distribution, classes were aggregated. To be more precise, it is only differentiated between farmers who act as innovators and those who primarily adopt new technologies. The latter category encompasses all early adopters, early majority, later majority, and laggards. To test which socio-economic characteristics relate to each class, a binary regression analysis is used.

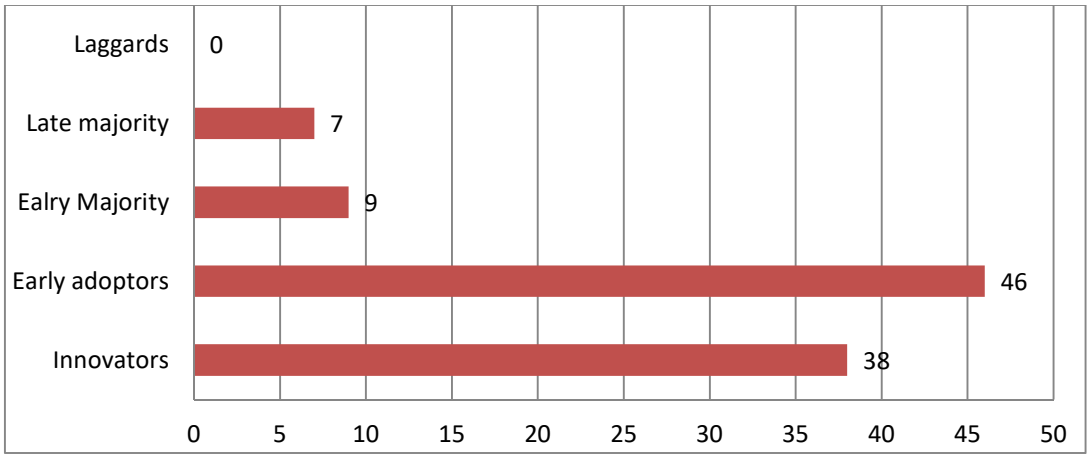

Figure 5:2 : Percentage of adopter categories in the study

Source: Author's own data (2016)

5.5. Research findings

5.5.1. Regression analysis for the farmers' adoption behavior

This study examined the farmers' adoption of novel paddy cultivation techniques introduced by agricultural extension officers. The adoption category of farmers was considered as a dependent variable and the socio-demographic characteristics of farmers were considered as independent variables. The results of the regression model fitted with the data are summarised in Table 5.1.

	B	S.E.	Wald	df	Sig.	Exp(B)
Age of the farmer	-.026	.036	.518	1	.472	.974
Farming experience	.027	.033	.641	1	.424	1.027
Education level	.142	.332	.183	1	.669	1.153
Farm size	-.222	.178	1.555	1	.212	.801
Access to extension	-.104	.064	2.640	1	.104	.901
Formal communication methods	-.057	.452	.016	1	.900	.945
Constant	1.36	1.800	.571	1	.450	3.900

Table 5:1 : Demographic and behavioral characteristic as determinants of adoption behavior: the economic results

Source: Author's own data, 2016

As Table 5.1 suggests, no aforementioned study hypothesis is fully supported. Only the farming level and education level shows the positive regression coefficient value. All other independent variables show negative coefficient values. Based on the research findings, all the hypotheses of the study will be rejected. Thus it is concluded that the socio-demographic characteristics of the farmers do not show any significant relationship with technology adoption behaviours of paddy farmers.

In the related literature, formal education and farming experiences have been considered the two most common measures of technology adoption. The impacts of those factors on technology adoption can be varied according to the nature of the environment. Farming experiences have been considered an adoption measure in a static environment in which knowledge accumulated with farming experiences, while formal education is used as measure of adoption in a dynamic political and economic environment where new technology and information are regularly developed (Uematsu & Mishra, 2010).

In contrast to this study, a number of empirical studies have shown the positive effect of education level on the adoption behaviour of farmers of various types of technology in agriculture. Education is found to have a positive impact on computer technology (Huffman & Mercier, 1991), internet access and internet purchasing (Mishra and Park, 2005; Mishra et al., 2009), technologies on cotton precision farming (Roberts et al., 2001), and herbicide tolerance technology (Fernandez-Cornejo et al., 2005).

Meanwhile, there is also some empirical evidence of insignificant or even negative effect of education on technology adoption. Farmers' education has insignificant effect on adopting on-site specific agriculture technology (Khanna, 2001) or fish production technologies (Nyaupane & Gillespie, 2009). Similar to the present research findings, Soule et al. (2000) discover the mixed effects of education on agriculture technologies. The authors find that education positively affects the adoption of land conservation technologies.

This study found that farm size did not affect paddy technology adoption, which is similar to the result found by Samiee et al. (2009) and Bonabana-Wabbi (2002) in their studies on integrated

pest management (IPM) technologies. However, Abadi Ghadim et al. (2005) demonstrate that farmers who own larger farms are more likely to adopt new technologies.

Additionally, in analysing the adoption of paddy technologies among farmers, no relationship is found between accesses to extension services on adoption. In contrast, Llewellyn and Scientific (2016) have cited that one of the factors significantly associated with adoption of integrated weed management practices is the greater use of extension services.

Formal communication methods were supposed to have higher preference for timeliness and accuracy and thus farmers would prefer to exchange information through the formal farmer network rather than through informal methods. Anyhow, this study has rejected the first hypothesis implying that paddy farmers in Hambantota district rely on informal communication channels to exchange information. A similar research finding appears in Just and Zilberman (2002) concerning wheat farmers, where 46 percent of the information used by wheat farmers is found to originate informally. Conley and Udry (2001, 2003) have also found that information about the proper use of new technology passes informally between farmers.

5.6. Discussion and conclusion

How can farmers acquire the necessary knowledge and information from other external sources about new technology? Further, once they do, how will it change their adoption behaviour? This research suggests that a farmer's external knowledge access and socio-demographic characteristics are critical to answering this question. It establishes the effect of formal and informal knowledge and data on the information sharing pattern varies depending on the access to same and the trust placed in the external information source.

This study found that nearly all information types were accessed and shared by farmers through formal channels. Among those formal approaches, the majority of paddy farmers mainly trusted the extension officer in their area and thus visited the AI most often for the knowledge and information they needed. Moreover, the AI officer in the area is the most influential actor who

can persuade farmers regarding the adoption of new technology. Therefore, technology promotion programmes initiated by the government effectively transfer information and knowledge to the farmers through the extension services. Furthermore, neighbours are the second most important information source for the paddy farmers in Hambantota District.

In the context of previous studies by several scholars (Bandiera & Rasul, 2006; Conley & Udry, 2010; Foster & Rosenzweig, 1995; Munshi, 2004; Pipy Fawole, 2008; Krishnan & Patnam, 2012), farmers share information with each other about farming issues, market information, and new technology. Moreover, as demonstrated by Lwoga et al. (2011), the knowledge and information needs and information seeking pattern of farmers are location specific.

In a farming community, farmers manifest varying socio-demographic characteristics that influence their technology adoption and knowledge sharing processes. Paddy farmers in Hambantota district are highly experienced farmers, with a mean of 26 years of farming experience and a mean age of 52 years. Further, the farmers have a mean 3.14 hectares of land each, implying commercial scale paddy farming in Hambantota district. The farmers have to travel a mean distance of nearly 7 km to meet extension officers to access knowledge and information regarding new technologies. As for education level, all of the farmers meet the adult literacy standard, having acquired formal primary education. Therefore, farmers in Hambantota district are sufficiently literate to understand information about technologies introduced by the extension services.

Further, a previous study on Sri Lankan paddy farmers in the dry zone (Siriwardana & Jayawardana, 2014) has shown that their mean age, experience, and educational level are similar to those of the farmers in this study. This shows that paddy farmers in Sri Lanka are highly experienced in farming due to it being the sole occupation for most and because their mean age is quite high. The age and experiences of paddy farmers might have some impact on the information sharing and technology adoption process.

This study has attempted to determine the farmers' adoption category simply by measuring the time taken, i.e. the interval between the introduction of a new technological development or process and its actual adoption by the farmer. Results show that a majority of the farmers in the

study are early adopters who wait just long enough to see the outcome of the technological programme that has been put into practice by one or more innovative farmers. Importantly, a majority of the farmers in the Hambantota district in Sri Lanka are either innovators or early adopters who have shown a significant adoption rate for new technologies. Among the factors that affect the information and knowledge sharing pattern of the farmers, information availability and social relationships proved to be the most important, while distance to information source and cultural proximity were the least important factors.

This study intends to determine if these research findings have any interesting research implications for the extension service that is engaged in popularising new paddy technologies and facilitating the knowledge diffusion process among paddy farmers in Hambantota district in Sri Lanka. The study could elaborate on important socio-demographic characteristics of paddy farmers that impact technology adoption. However, it did not find any significant relationship between the demographic characteristics and the technology adoption of paddy farmers. Further, farmers were highly dependent on agricultural extension officers for acquiring knowledge and information, which they also obtained to a lesser extent from their neighbours. Therefore, the extension officer in the area was considered to be the most influential actor in the technology adoption process and regarded as the most important source of information. Hence, the Sri Lankan government can easily introduce agricultural technologies to rural paddy farmers through the services of extension officers. Moreover, paddy farmers in Hambantota district tend to share information with other farmers in the community when they have some useful information to impart, especially if they are in close proximity and linked to the same social network as others. Despite these factors, statistically none of the aforementioned hypotheses was significantly associated with technology adoption of paddy farmers in Hambantota district.

This study falls into the research class that is based on the static nature of data, and that is a serious weakness. All the analyses were based on a particular farmer group practicing the same paddy development technologies introduced by extension officers. Therefore, this study might have a bias towards the extension agents and their adoption decision and knowledge sharing exercise as against the other members of the community who were also part of it. Moreover, the

farmers' adoption behaviours were assessed based only on their perceptions; hence, this could conceivably limit the reliability of the results.

Chapter 6

Factors constraining the adoption of new agricultural technologies by paddy farmers in the Hambantota district of Sri Lanka

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Abstract: Agricultural technologies are seen as important driving factors in boosting production in developing countries. However, the rate of adoption of these technologies has remained low. In spite of intensive research, the identification of the most important factors that hinder quicker adoptions is still a difficult task. This study aims at narrowing the gap by empirically identifying technological, economic, and social factors that constrain knowledge acquisition and diffusion in this context. This study is based on the adoption of agricultural technologies by paddy farmers in Hambantota district, as evaluated from the perspective of agricultural extension officers. The empirical results highlight that only 40 to 60 percent of farmers are actually inclined to adopt new agricultural technologies, whereby technological constraints are shown to be the most dominant adoption barriers. Therefore, this study recommends that approaching these constraints as a way to overcome them is crucial for the technological upgrading of agricultural production in developing countries.

Keywords: *Adoption stages, Agricultural technology, Constraints, Information & knowledge*

6.1. Introduction

Agricultural technologies encompass all kinds of improved techniques and practices that can increase the growth of agricultural output. Their advancement has substantially shaped agricultural production and development in recent decades. Although many modern agricultural technologies have been invented in developed countries, not all of them have found their way into developing countries despite modern agricultural technologies being seen as an important route to alleviate poverty. For instance, it is widely accepted that adopting new and improved technologies increases production and helps upgrade socio-economic conditions in rural communities (Kasirye, 2010). Hence, the adoption of new and improved technologies is seen as a major factor in the success of the 'Green revolution' in Asian countries (Munshi, 2004). Nevertheless, the adoption rate of new technologies has been and still remains low in most developing countries (Bandiera & Rasul, 2006; Mwangi & Kariuki, 2015).

There exists a vast swathe of literature studying the factors determining agricultural technology adoption (Mwangi & Kariuki, 2015; Katungi & Akankwasa, 2010; Akudugu et al., 2012; Loevinsohn et al., 2012; Adesina & Baidu-Forsen, 1995). Many studies in this field have highlighted two major groups of factors behind successful agricultural technology adoption in developing countries. The first group includes economic, social, and institutional factors. Economic factors include farm size, cost of adoption, access to credit, expected benefits from the adoption, and off-farm income generation activities. Social factors comprise the age of farmers, level of education, and gender. Institutional factors mainly refer to the presence of agricultural extension services (Akudugo et al., 2012).

The second major group, which is the focus of the present paper, deals with farmers' access to knowledge of and about new agricultural technologies. According to most traditional studies and in particular Rogers (1995), farmers are most likely to obtain such knowledge from their own experimentation and from neighbouring farmers through social interaction.

Though a number of studies have been conducted on technology adoption considering these two groups of factors, their relative importance in the context of developing countries is still unknown. This is undoubtedly due to the limited availability of data. The present study attempts to fill this gap by means of an empirical analysis. In addition, this study highlights the relevance of political support rendered for the adoption of new technologies. The latter is of substantial relevance in developing countries because farmers increasingly interact with extension officers, agricultural instructors, and sales agents in technology adoption processes. From a knowledge diffusion literature standpoint, these can be seen as change agents, as they introduce new technologies to communities, i.e. farmers in specific regions (Rogers, 1995). Not surprisingly, they have been identified to greatly impact technology adoption (Mwangi & Kariuki, 2015; Genius et al., 2010; Uaraeni et al., 2009).

In the present study, AIs are not only seen as participants in technology diffusion, but also utilise their expertise to learn about how this process takes place in their respective areas. More precisely, it investigates the AIs' perceptions on how farmers adopt new technologies and the factors that influence these decisions. As an empirical case, the focus is the technology adoption pattern of paddy farmers in Hambantota district in Sri Lanka. Thereby, it contributes to the still underdeveloped literature on factors influencing the spread of modern agricultural production technologies in developing countries. Additionally, insights into knowledge sourcing and learning of small-scale paddy farmers in Sri Lanka are provided.

The empirical results highlight that only 40 to 60 percent of farmers are actually inclined to adopt new agricultural technologies, whereby technological constraints are shown to be the most dominant adoption barriers for the Yaya 2 and FFS programmes. The FFS programme is constrained by a 'lack of knowledge and resources', 'lack of [technological] compatibility', 'availability of extension services', 'lack of technical knowledge', and 'lack of reliable information sources'. In reference to the Yaya 2 programme, 'economic and environmental barriers', 'lack of trust in the extension services', 'lack of information and training', and 'poor information link' were major constraints for adoption.

This paper is structured as follows. Section 2 gives an overview of the theoretical background of technology adoption and diffusion. Section 3 introduces the empirical data and methodological approach. The results will be presented in Section 4. The discussion and conclusions are elaborated in Section 5.

6.2. Determinants of agricultural technology adoption

6.2.1. Technological, economic and personal factors

Adoption and diffusion are the processes shaping the spatial and temporal dimension of innovation utilisation. The diffusion of technology is the result of cumulative adoption (Sunding et al., 1999). Rogers (1983), defines diffusion as the process by which an innovation is communicated through different channels over a period of time among the members of a social system or population (see also OECD, 2001).

Notably, determinants of technology adoption vary in their importance over the course of its diffusion and adoption processes. The adoption of technologies is a dynamic process that follows hierarchical or pyramid-like stages, namely awareness, interest, evaluation, trial, and adoption, which are described in detail by George and Bohlen (1956) (as cited in Ovwigho, 2013). Awareness means that an individual is aware of the existence of a technology. Interested individuals usually want more information to assess if the technology is helpful. In the evaluation stage, individuals assess the potential utility of the technology based on the information they have gathered. In the trial stage, individuals test the technology to see if it meets their expectations. Finally, individuals reach the adoption stage when they decide to implement the new technology and make actual use of it. Some individuals go through this five-step process in rapid succession; others are slower in transition between steps, which again depends on technology and individual-specific factors (Ovwigho, 2013). At each stage different factors play a role or vary in their relevance. For instance, during the awareness stage, external information and knowledge sources are crucial in providing necessary inputs. The processes, adoption, and diffusion stages are shaped by characteristics of the social systems, general circumstances, and

by the characteristics of technologies such as relative advantages, complexity, and divisibility (OECD, 2001).

Many studies have investigated technology diffusion in different contexts. However, few studies have done so with respect to developing countries (Lybbert & Sumner, 2012; Abdulai & Huffman, 2005). Accordingly, little is known about the factors impacting technological diffusion processes in this context. This is even more so with respect to agricultural technologies that are particularly crucial for the economic development of these countries. Existing research highlights that farmers' technology adoption decisions are shaped by the dynamic interaction between the characteristics of technologies and the socio-economic circumstances associated with the adopter group (Loevinsohn et al., 2013; Akudugu et al., 2012). On this basis, the determinants of agricultural technology adoption are classified into three categories: economic, social, and institutional.

Economic factors: Foster and Rosenzweig (1995) state that the availability, affordability, and farmers' expectations about the long-term profitability of new technologies are important determinants of adoption. Costs of adoption may be substantial in some cases. For instance, test facilities may be required such that farmers can observe and experience the contribution of new technologies on productivity and profitability (Doss, 2003). Foster and Rosenzweig (2010) and Muzuri et al. (2013) also identify the costs of hired labour and the unavailability of necessary resources as important factors constraining technology adoption in the case of farmers in Kenya. Personal income, tenure status, and the availability of credit are similarly decisive in these contexts ((Sunding et al., 1999). The first hypothesis summarises these arguments.

H1: Economic and environmental barriers hinder the adoption of agricultural technologies in developing countries.

Social factors: Personal characteristics such as education, age, and gender have been shown to play a role in technology adoption in the context of agricultural technologies in developing countries (Fernandez-Cornejo & Daberkow, 1994; Mignouna et al., 2011; Keelan et al., 2014). In

particular, the education level of farmers raises their ability to obtain and use information relevant for the application of technologies (Lavison, 2013; Mignouna et al., 2011). According to Mwangi and Kariuki (2015), Okunlola and Oludare (2011), and Waller et al. (1998), higher levels of education also influence farmers' attitudes positively, making them more open, rational, and more objective in their evaluation of the benefits of a new technology. This is taken up in the second hypothesis.

H2: Lack of knowledge and experience reduces the likelihood and success of technology adoption.

Institutional factors : Sunding et al. (1999) confirm that family size of farmers and their values as well as beliefs in the farming communities support technological adoption. Farmers perceiving a new technology as compatible with their needs, environment, and cultural context are more likely to adopt it (Mignouna et al., 2011). Moreover, regulations, the legal framework, and other factors related to the institutional framework under which farmers operate are shown to be of relevance in this context (Foster & Rosenzweig, 1996; Rogers, 2003; Koppel, 1994; Kohil & Singh, 1997; Uaiene, 2009). Therefore, the third hypothesis addresses these aspects.

H3: Institutional and cultural factors shape the adoption of agricultural technologies.

6.2.2. Factors associated with knowledge and information sharing process

Information on Technology: The present study focuses on another much less investigated factor that influences the adoption of new technologies in developing countries, namely the access to information about new technologies. Accessing information on new technologies is a prerequisite for farmers to learn of their importance (Mwangi & Kariuki, 2015), as farmers can only adopt the technologies of which they are aware. In addition, Bonbana-Wabbi (2002) argues that easy access to information reduces uncertainties about new technologies, which allows for more informed decisions. Once farmers obtain information about new technologies, they subjectively evaluate it. Although this is recognised as a prerequisite in later stages of the adoption process, access to information can have both positive and negative impacts on

technology adoption. If information confirms the benefits of a technology farmers expect, that will support adoption. In contrast, more information may lead to a rejection of technology when this confirmation does not take place (Uaiene et al., 2009). Technology adoption is not always positive, as adopters may also hinder the other farmers' adoption, inserting substantial negative effects. In any case, more information will always lead to better decision making of farmers, which in turn will support the adoption of technologies with higher added value. Alternatively, a lack of timely and reliable information will constrain the adoption of technologies with high value added. Hypothesis four represents these ideas.

H4: Farmers' technology adoption is constrained by lack of reliable and adequate information sources on new technologies.

Social networks: Information on new technologies is not easily or readily available everywhere. It diffuses through various channels. Social networks are one such crucial medium. Katungi and Akankwasa (2010) observe that farmers who participate in farming organisations acquire more knowledge about technology through social learning. Hence, farmers who interact with other farmers are more likely to adopt new technologies. Alternatively, information on new technologies might be 'pushed' to farmers by extension services. As this learning process involves face-to-face interaction, it represents a form of social learning. These services have been found to be of crucial importance for technology adoption in developing countries (Akudugoet al., 2012; Mwangi & Kariuki, 2015; Uaiene et al., 2009; Mignouna et al., 2011; Serunkuuma, 2005). In contrast, poor information links will inhibit technology adoption. The final hypothesis summarises these arguments.

H5: Weak social links that do not fuel information exchange among farmers will reduce technology adoption.

Interestingly, most studies in this field focus on the relevance of access to information on new technologies in the context of developed countries. Agricultural innovation systems in developed countries significantly differs from those in developing countries due to resource availability and

the types of actors involved in the process. Knowledge transfer processes in developing countries involve diverse sets of actors including market and non-market institutions, as well as public policy, which tends to be less present or less effective in developing countries (Spilman, 2005). Moreover, access to new information and advanced information and communication technology facilities facilitates knowledge diffusion in developed countries. This is further enabled by the generally higher levels of education and greater financial capabilities of farmers in these countries in comparison to those in developing countries (Uematsu & Mishra, 2010; Young, 2009).

Given these massive differences and the literature's focus on developed countries, little is known about these factors' relevance in the diffusion process of agricultural technologies in developing countries. This study closes this gap by means of an empirical study on technology adoption of paddy farmers in Hambantota district in Sri Lanka.

6.3. Empirical approach

6.3.1. Data collection

The empirical study applies a novel perspective, which provides detailed information on how the technology diffusion process takes place in the context of the agricultural sector in a developing country. More precisely, we use the perspectives of AIs who serve as extension personnel. These connect with farmers and examine the technology diffusion process as well as the adoption process of farmers.

That case study is based on data collected from paddy farmers in the Hambantota district of Sri Lanka. The majority of paddy farmers in Hambantota district are solely paddy farmers and their main occupation is farming. On average, the age of a paddy farmer is 53 years and each possesses 26 years of experience (see for a detailed description of this community, Silva & Broekel, 2019). These farmers are served by 30 AIs, who are responsible for the introduction of new technologies, knowledge, and innovation on new paddy technology programmes.

In general, farmers are argued to have conservative attitudes and need much time and information to be persuaded to adopt new technologies (OECD, 2001). However, this is not necessarily always the case in developing countries (Silva & Broekel, 2019). Nevertheless, there tends to be a significant time lag between the invention of new technology and its adoption by farmers. To make this process quicker and more efficient, the dissemination of information among farmers is crucial. This is where extension services come into play. In general, extension services and research institutes work together to ascertain that the field level issues, innovations, and technological needs of farmers are addressed. When introducing new technological programmes to farmers, all AI officers are given a pre-seasonal training programme to guide farmers through technology adoption. Therefore, extension officers are well aware of new technologies and information released by research officers and institutions. In addition to the introduction of new technologies, AI officers also periodically monitor and evaluate the application of new technologies by farmers. They also report and assess the adoption rate of farmers and the constraints of adaptation to new technologies.

AI officers are assigned by the Department of Agriculture to specific areas. They are responsible for introducing new technologies, solving field level issues, and maintaining good relationships with farmers in their areas. AI offices are located within their respective areas and officers are expected to meet farmers every day except on Wednesday. On Wednesday, AI officers meet up with one another at the Department of Agriculture. In addition, AI officers are reachable by farmers via mobile phones. Generally, AI officers are well equipped and set up to do these jobs and they maintain close relationships with the farmers in their sector of operation. Hence, AI officers have a good understanding of farmers, their activities, and the adoption of new technologies. Consequently, they are great sources of providing information on technology adoption in developing countries. To exploit this situation, AI officers were interviewed for this project with respect to the technology adoption behaviours of paddy farmers in Hambantota district. For this purpose, semi-structured face-to-face interviews, each lasting for about 20 minutes, were conducted. To measure the extent of agreement on specific issues, a five-point Likert scale, providing response options ranging from ‘not at all’ to ‘a very great extent’ was

scaled from -2 to +2. This follows the approach of Samiee et al. (2009) and Agwu and Anwanwu (1996). In particular, the questionnaire was designed to measure farmers' adoption rates and identify factors constraining the adoption of two technological programmes introduced by the Department of Agriculture. The programmes are the Farmer Field School (FFS) and Yaya 2 programme that are coordinated and facilitated by AI officers.

The Farmer Filed School programme

The FFS programme was developed to help farmers tailor various agricultural technological practices. The FFS was first introduced in Sri Lanka to demonstrate integrated pest management (IPM) practices to paddy fields. It is a form of adult education programme involving practical, field-based learning in weekly sessions during a complete crop cycle. It also includes field school curricula encouraging learning from peers and strengthening communication skills and group cohesion (Pontius et al., 2002). This programme primarily uses non-formal education methods to teach farm leaders in each community on how to reduce pesticide use, which in turn helps increase farm income. However, evaluations of this programme have identified this approach as a relatively expensive and labour-intensive extension model that reaches only a small number of interested farmers (Tripp et al., 2005). With the onset of each cultivation season of paddy, AIs of each division regularly initiate the FFS programme for the farmers in the area once a week. In addition, AI officers visit farmers to address issues arising in the fields.

Yaya *2* programme

Yaya 2 is a major agricultural technological programme that has been developed for paddy farmers in Sri Lanka. It is aimed at introducing eco-friendly technologies to increase paddy production to 5mt/ha. Currently, the average yield per hectare in Sri Lanka is just 4.3 mt/ha. Hence, the Yaya 2 programme has been set up to increase the paddy production by nearly 1 mt/ha. This programme addresses most crop cultivation practices of paddy farming. For instance, it targets seasonal cultivation practices, the production of high-quality seed paddy, the use of organic and chemical fertilizers, weed control practices without weedicides, different nursery

technologies, integrated pest management, mechanisation, efficient water management practices, etc. Consequently, it offers farmers a full bundle of new technologies that they can adopt to increase their production.

6.3.2. Data on different stages

The empirical analysis is built on 30 interviews focusing on the factors influencing the diffusion of the technologies promoted by these two new programmes (FFS and Yaya 2). The dependent variable is the level of adoption of these two programmes. As pointed out above, there are good reasons to assume that many factors influence the diffusion of technology at different stages of the adoption process. An individual empirical analysis is therefore conducted at each of the five stages based on the following themes: awareness, interest, evaluation, trail, and adoption.

AI officers were asked to assess farmers' involvement and degree of completion with respect to each stage. Such information is available to the officers, as they are obliged to visit farmers at the beginning, middle, and end of the process of introducing a new technology. Further, they need to maintain records about the farmers' adoption rate at the different stages.

To assess farmers' status with respect to the awareness stage, this approach measures their awareness of the two support programmes (FFS and Yaya 2) by considering the percentage of farmer participation in the awareness activities offered at the initial stage. Hence, these farmers signal a general openness to innovation. The typical behaviour during the interest stage is to actively seek information about an innovation. To approximate this, AI officers were requested to provide the percentage of farmers who requested further information on the two programmes.

In contrast to these relatively straightforward approaches, empirically capturing the trial stage is rather difficult as this period is a reflection of mental trials by individuals. As an approximation, the percentage of farmers are considered who showed interest in heeding the successful stories from the technological programmes, i.e. farmers who seek to evaluate the programmes through other farmers' success stories. Such farmers are assumed to be passing through the evaluation stage (Tripp et al., 2005). During the trial stage, farmers should use new technologies on a small scale to explore its usability at larger scales. AI officers keep statistics of farmers who maintain

small demonstration plots in their paddy fields. The percentage of farmers actively involved in these demonstrations was used to confirm their engagement in the trial stage. AI officers are also aware of farmers who completely adopted new technology, i.e. those who make actual use of it with a significant magnitude at their fields. Hence, to analyse the number of farmers who successfully adopted new technology in their fields, related statistics were obtained from the AIs. In addition to this information concerning the five stages, unawareness and discontinuation as controlled situations are also investigated. This information is obtained from the AI officers who witnessed farmers discontinuing the use of new technologies in the subsequent cultivation season. Further, these AI officers maintain records of farmers who were not followed up. These farmers are assumed to be unaware of the programmes and the corresponding technologies.

6.3.3. Descriptive of technology diffusion

Before exploring the relative importance of different factors in each of the five stages, it is important to take a look at the data from a descriptive perspective. Table 6.1 depicts the percentage of farmers who adopted new technologies as perceived by AI officers with respect to their area of surveillance. As a representation, the average of the values across the 30 responses from the AI officers was calculated. These AI officers mainly focus on paddy farming and other crops that fall within their field of expertise. Note however, that these averages reflect different numbers of farmers because the numbers in an officer's surveillance area varies. More precisely, AI officers provided the percentage of farmers who are practicing a specific (new) technology during a certain time period and that eventually completely adopted it. Farmers who practice technologies for a short period without finally adopting it were not considered.

Percentage of farmers who effectively adopted new technologies and shared information on this	Mean response of AI officers (Percentage)
Almost all farmers	0
80-100 % of farmers	3
60-80 % of farmers	10
40-60% of farmers	37
20-40 % of farmers	27
10-20 % of farmers	23
Only wise farmers	0

Table 6:1: Farmers' technology adoption and knowledge dissemination process

Source: Author's own data (2016)

None of the AI officers experienced a full adaptation of the promoted technologies by all of their farmers. Although farmers within the same community tend to plant the same crop, they still seemed to be heterogeneous in terms of adopting new technologies. This indicates that the technology adoption decision is impacted by varying factors within (and among) these communities. On average, 40–60 percent of the farmers adopt a new technology. Accordingly, there seem to be some farmers in Hambantota district who are either not interested or unwilling to adopt any new technologies, or who have to be motivated for the technology adoption. Table 6.2 illustrates a more detailed view into the diffusion process. It shows the average percentage of farmers who have reached different stages of adoption as perceived by AI officers

Adoption stage	Percentage of farmers	
	FFS Programme	Yaya 2 Programme
Unaware	0	0
Aware	80	83
Interest	60	76
Evaluation	57	71
Trial	54	64
Adoption	45	50
Discontinuance	16	9

Table 6:2 :Percentage distribution of farmers in adoption process

Source: Author's own data (2016)

The table highlights significant variations in the adoption rates. Onweremad and Njoku (2007) give some possible explanations. For instance, this variation might be due to few contacts between extension officers and farmers. However, other factors may also play a role, which will be explored in the subsequent parts of the chapter.

6.3.4. Constraining factors in the adoption process

Eight variables approximating technological and socio-economic factors that are likely to impact the technology adoption process are considered in the study (Annex 6A). These are complemented by six variables reflecting factors associated with knowledge and information sourcing.

The difficulty of integrating new technologies (DIFF) into the existing farming system is the first variable belonging to the technological factors. It approximates the challenges farmers face when they integrate new technologies into their traditional farming system. Technologies that are introduced to farmers are usually more complex than the ones already in use, which requires integration efforts to be made. Further, two other variables are considered that reflect that the integration will be more challenging when farmers lack adequate education, qualifications, and

experiences (LACK_EDQUEXP) (Adebiyi & Okunlola, 2013; Okunlola, 2011; Ovwigho, 2013; Samiee et al., 2009). Moreover, the lack of technical knowledge about new technologies is considered (LACK_TECH), as there are technical aspects which cannot be easily detected by farmers when using technology. Socio-economic environmental factors such as climate and soil conditions that may impact technology adoption are also included. The factors are summarised as environmental barriers (ENVIRON).

Carrying out new technologies in the existing paddy fields is a complex process (COMPLEX) due to the heterogeneity of farming fields in different areas. Generally, rural farmers have few resources. However, some might possess more comparatively, which feeds into the variable RESOURCE. Similarly, the technologies with high cost of usage are less likely to be adopted. This is considered by the variable COSTS. The last socio-economic factor considered is the specific areas in Sri Lanka which differ culturally and ethnically. This particularly matters for female farmers who encounter problems in using and adopting new technologies in their fields. The variable CULTURE approximates the mismatch between existing cultural practices and new technologies.

The other constraining category comprises factors associated with knowledge and information sharing. Most importantly, it is the lack of adequate information sources on new technologies that may hinder technology adoption. The variables LACK_INFO and UNAVAILABLE evaluate these aspects. Poor information and information sharing activities of farmers are considered as other constraining factors (WEAK_SHARE). However, even when the information is available and diffused, some traditional farmers may not trust available information sources, which will be presented by the variable LACK_TRUST. Although such obstacles could be avoided through extension services and social learning, they may not always be successful due to the factors mentioned above. In addition, a lack of technical training, advice, and insufficient meetings with technical specialists are considered additional constraining factors under knowledge and information sharing. These are approximated by the variables LACK_SPEC and LACK_ADVISE. The precise definitions and questions used to gather the appropriate information for all variables are presented in Annex 6A.

The empirical sample of the study is relatively small, comprising only 30 observations. To conduct multivariate analysis, these variables are condensed by means of a factor analysis with Varimax rotation. The values of some of the explanatory variables differ between the two programmes (FFS and Yaya 2). Therefore, two separate factor analyses are conducted using the program-specific values. The decisions of factor aggregation are based on the loadings (beta weights). Moreover, Kaiser's criterion is used to choose the appropriate number of factors and loadings above 0.3 are utilised to name and interpret factors (Madukwe, 1996; Agwu & Anyanwu, 1996). To ensure a meaningful interpretation, factor analysis was employed to combine thematically related variables, i.e. variable belonging to the same thematic group outlined above.

As the second step, the obtained factors enter a number of regression analyses as explanatory variables, with each model focusing on one programme and adoption stage. For each stage, the shares of farmers having successfully completed it (as indicated by the AI) represent the dependent variable and the above factors as explanatories.

6.4. Results and discussion

6.4.1. Factor analyses

Factors constraining the adoption of the *FFS* programme

Table 6.3 depicts the results of the factor analysis for the technological and socio-economic factors related to the adoption of the FFS programme. The first factor is dominated by the variables representing the inadequacy of technical knowledge about new technologies (LACK_TECH) (0.65), lack of resources to implement new technologies (RESOURCE) (0.59), and the high cost of such technologies (COSTS) (0.71). Therefore, it is interpreted as indications of 'lack of knowledge and resources'. The second factor rather corresponds to 'lack of [technological] compatibility', as it summarises variables such as the difficulty in integrating new technologies into the existing farming system (DIFF) (0.79), and the incompatibility between traditional culture and modern technology (CULTURE) (0.67).

Technological and Socio-Economic factors	Factor 1 (lack of knowledge and resources)	Factor 2 (lack of compatibility)
DIFF	0.100	0.790
LACK_EDQUEXP	0.039	0.262
LACK_TECH	0.654	-0.195
ENVIRON	-0.102	-0.237
COMPLEX	0.127	0.076
RESOURCE	0.593	-0.033
COSTS	0.715	0.244
CULTRUE	-0.239	0.666

Table 6:3: Varimax Rotated Technological and Socio-Economic factors constraining the adoption of FFS programme

Source: Author's own data (2016)

In Table 6.4, the results of the factor analysis for the knowledge and information sharing variables in the context of the FFS programme are shown. These variables were condensed into three factors. Factor 1 is labelled the 'availability of extension services' because it is dominated by the unavailability of necessary information associated with new technologies (UNAVAILABLE) (-0.83)

and the lack of extension services (LACK_ADVICE) (0.76). The negative values of variable UNAVAILABLE indicate that while sufficient information is available about the FFS programme though the influence of extension workers, it is not sufficient for its adoption.

The second factor represents 'lack of technical knowledge' and the score is strongly negative on inadequate sharing of knowledge with other actors of the network (WEAK_SHARE) (-0.73), whereas the score of lack of technical training and interaction with technical specialist is strongly positive (LACK_SPEC) (0.74). This indicates that the farmers are willing to share their knowledge with other actors of the network although farmers are less knowledgeable in technical aspects. Factor 3 is dominated by the variables indicating the lack of adequate information sources on new technologies (LACK_INFO) (0.73) and the lack of trust in available information and information sources (LACK_TRUST (0.69). Accordingly, this is interpreted as 'lack of reliable information sources'.

Factors associated with knowledge and information sharing	**Factor 1 (availability of extension services)**	**Factor 2 (Lack of technical knowledge)**	**Factor 3 (lack of reliable information source)**
LACK_INFO	0.291	0.s224	0.730
WEAK_SHARE	0.061	-0.728	0.237
UNAVAILABLE	-0.835	0.173	0.015
LACK_TRUST	-0.265	-0.213	0.688
LACK_ADVICE	0.765	0.303	0.034
LACK_SPEC	0.161	0.739	0.311

Table 6:4 : Varimax Rotated Factors associated with knowledge and information sharing that constrains the adoption of FFS programme.

Source: Author's own data (2016)

Factors constraining the adoption of *Yaya 2* programme

Technological and Socio-Economic factors

Table 6.5 shows the combined technological and socio-economic variables related to the adoption of Yaya 2 programme. Two factors are extracted. The first is 'economic and environmental barriers', which is dominated by environmental barriers associated with using new technologies (ENVIRON) (0.83), complexity in carrying out practices related to new technologies in the field (COMPLEX) (0.50), and the high cost of the new technologies (COSTS) (0.63). The second factor summarises the 'lack of knowledge and experience'. It comprises the variables lack of adequate educational qualifications and experience (LACK_EDQUEXP) (0.89) and the high cost of new technologies (COSTS) (0.60).

Technological and Socio-Economic factors	Factor 1 (economic and environmental barriers)	Factor 2 (lack of knowledge and experience)
DIFF	-0.191	-0.060
LACK_EDQUEXP	0.007	0.893
LACK_TECH	0.153	-0.055
ENVIRON	0.834	0.043
COMPLEX	0.505	-0.362
RESOURCE	-0.155	0.193
COSTS	0.630	0.605
CULTURE	0.148	-0.239

Table 6:5 :Varimax Rotated Technological and Socio-Economic factors constraining the adoption of Yaya 2 programme

Source: Author's own data (2016)

Lastly, the variables associated with knowledge and information sharing, which constrain the adoption of the Yaya 2 programme (Table 6.6), are condensed into three factors. Factor 1 is interpreted as 'lack of trust in the extension services'. It is mainly shaped by lack of trust in

available information and information sources (LACK_TRUST) (0.70) and the lack of influence of extension services and social learning (LACK_ADVICE) (0.76). The loadings for the second factor 'lack of information and training' suggest the inclusion of the lack of adequate information sources on new technologies (LACK_INFO) (-0.72) and the lack of technical training and interaction with technical specialist (LACK_SPEC) (0.77). As pointed out above, the negative loading of LACK_INFO implies that farmers have adequate information sources on new technologies, while having less interaction with technical aspects of the new technology. Factor 3 is called 'poor information link' and it is dominated by poor information links and minimal sharing with other actors of the network (LACK_SHARE) (0.87) as well as the unavailability of important information required to utilise the new technologies (UNAVAILABLE) (0.57).

Factors associated with knowledge and information sharing	**Factor 1 (lack of trust in extension services)**	**Factor 2 (lack of information and training)**	**Factor 3 (poor information link)**
LACK_INFO	-0.463	-0.716	-0.005
WEAK_SHARE	0.189	-0.123	0.874
UNAVAILABLE	-0.284	0.498	0.570
LACK_TRUST	0.707	0.052	-0.015
LACK_ADVICE	0.762	-0.113	0.102
LACK_SPEC	-0.169	0.768	-0.042

Table 6:6 : Varimax Rotated Factors associated with knowledge and information sharing that constrain adoption of the Yaya 2 programme.

Source: Author's own data (2016)

6.4.2. Regression analysis to explain variations in adoption level

In the second stage, the factors created above are related to the shares of farmers that have completed the different stages of the adoption process of the two programmes. Given the continuous nature of the dependent variables and the fact that their values are usually relatively

far off the extreme values based upon percentages (0 and 100), standard OLS regressions are employed.[13]

Although the variables are condensed into a few factors, the availability of only 30 observations and five explanatory variables is problematic. However, since the R^2 values are quite low (less than 0.3), some adjusted R^2 drop into negative values (see Tables 6.8 and 6.10). Nevertheless, this should not be over interpreted. Accordingly, there is still a lot of unexplained variance and hence, other factors that matter beyond the ones considered in the present study.

The findings on the regression coefficients for the FFS programme are summarised in Table 6.9. In the empirical setting of the paper, a significance level of 0.1 is considered sufficient for the production of a sound interpretation. Accordingly, the factors 'lack of compatibility' and 'availability of extension services' (p=0.024) are found to be relevant factors for the adoption of technologies promoted by the FFS programme in the awareness stage, adoption stage, and discontinuation stage, respectively.

The findings on the importance of the availability of the extension services confirm the prominent role attributed to such services in the literature. For instance, Samiee et al. (2009) also reveal that extension services have a significant and positive correlation with the adoption process. However, in the context of the present paper, the interpretation of this variable is somewhat difficult, as the opinions about the adoption of technologies are elicited from the extension officers and not the farmers. Accordingly, this variable includes (implicitly) a reflection on the effectiveness of the extension officers. Finding a positive relationship (at least in of the considered adoption stage), therefore confirms that these technologies are unlikely to diffuse if not pushed by the extension services. It is also in line with the theory that these services primarily matter for the adoption stage (significant) and the awareness stage (barely insignificant with p=0.108). These stages are particularly crucial for the final decision to go through with an adoption and for raising awareness of new technologies in the first place.

[13] Log-transformed values were alternatively considered. However, this did not change the results significantly.

The issue of lacking complementarity of the FFS programme to farmers' needs is confirmed by the analysis. Accordingly, the results support the decision to discontinue this programme precisely for this reason. Therefore, an alternative programme for FFS programme should be developed through collaborative discussions between researchers and the farmers.

The results of the Yaya 2 programme are presented in Table 6.11. Surprisingly, none of the explanatory factors turn out to be significant. Most likely, this is due to the relatively low numbers of observations (30). The results also contrast those of the FFS programme, for which some significant relationships were found.

6.5. Discussion and conclusion

The empirical results must be seen in the light of some empirical limitations. The questionnaire used to measure the adoption of new agricultural technologies is based on the perception of AI officers who simultaneously serve as the external influencing agents for the adoption process. In contrast, most of the previous studies have measured technology adoption based on farmers' perceptions. Although this can be seen as a strength in achieving more objectives and eliciting complete information, it might be problematic since AI officers are also responsible for helping farmers adopt the technologies introduced by the two programmes. Accordingly, to some extent they are evaluating their own effectiveness in terms of technology diffusion. This may have induced certain self-perception and self-assessment biases. In addition, the empirical dataset is limited to 30 interviews, which are very detailed in terms of the information provided but very restrictive in their absolute numbers.

Nevertheless, the results of this study have some interesting research implications. First, the study shows that the adoption of a new paddy cultivation technology by farmers in Hambantota district varies between farming communities from 40 to 60 percent. It is also revealed that the percentage distribution of farmers across different adoption stages differs between the FFS and Yaya 2 programmes. The general numbers are thereby very much in line with what has been reported elsewhere (Muange & Schwarze, 2014; Uaiene et al., 2009; Bandiera & Rasul, 2006).

In contrast to the Yaya 2 programme, the study identified factors constraining farmers' adoption of FFS programming. Significantly, factors such as lack of knowledge and resources and a mismatch between the programme technologies and farmers' needs (lack of compatibility with existing farming practices) are identified. With respect to the first factor, this study shows that extension services are particularly important in raising farmers' awareness of such new technologies and for making the final decision on whether to adopt a technology.

One limitation of this study is in identifying systematic factors constraining the adoption of technologies promoted by Yaya 2 programme. Why the adoption process differs between these two programmes is certainly an issue that also needs to be addressed by future research.

These research findings suggest some policy implications that are particularly relevant for the Sri Lankan context. Some of the factors that have been identified to have hampered the diffusion of the FFS programme (lack of compatibility, access to extension services) seem to have already been addressed in the design of the Yaya 2 programme. Nevertheless, extension services do not seem to play a supportive role in adopting technology in the Yaya 2 programme. This raises some questions on whether the Yaya 2 programme is worth continuing, as it is not properly supported by extension services. Future research needs to address how to improve the programme to increase paddy production. The study further reveals that technology adoption is constrained due to poor technical knowledge regarding new technologies. Therefore, educational programmes focusing on this aspect might be a valuable option to increase technology adoption.

The FFS programme is based on learning through discovery and experimentation. It further strengthens group cohesion and teamwork. Therefore, the programme can be seen as a social empowerment programme going beyond agricultural aspects. According to Gallagher (2000), this programme promotes the empowerment of farmers by building human and social capital. Future research should focus the aforementioned factors and study the social impact of the FFS programme and analyse its impact on social learning.

Based on the Sri Lankan scenario, many farmers are no longer interested in continuing new technologies due to a perceived lack of compatibility. Therefore, researchers and extension staff must work collaboratively to find solutions relevant to local needs and conditions. Moreover,

future research can ascertain the farmers' actual needs through a systematic needs assessment process.

Annex 6.A

	Technological and Socio- Economic factors
1	Difficulty of integrating new technologies into the existing farming system. (DIFF)
2	Lack of adequate educational qualifications and experiences. (LACK_EDQUEXP)
3	Lack of adequate technical knowledge about new technologies (LACK_TECH)
4	Environmental barriers of using new technologies (ENVIRON)
5	Complexity in carrying out associated practices related to new technologies in the field. (COMPLEX)
6	Lack of resources to carryout necessary activities associated with new technologies (RESOURCE)
7	High cost of new technologies use (COSTS)
8	Cultural incompatibility of technology adoption (CULTRUE)
	Factors associated with knowledge and information sharing
1	Lack of adequate information sources on new technologies (LACK_INFO)
2	Poor information link and sharing with other actors of the network (WEAK_SHARE)
3	Unavailability of necessary information associated with new technologies (UNAVAILABLE)
4	Lack of trust on available information and information sources (LACK_TRUST)
5	Lack of influences of extension services and social learning (LACK_ADVICE)
6	Lack of technical training and meeting with technical specialist (LACK_SPEC)

Table 6:7: Factors constraining technology adoption

Factors constraining for FFS Programme adoption

Model Summary Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Awareness stage	.590[a]	.348	.212	3.637
Interest stage	.362[a]	.131	-0.05	5.854
Evaluation stage	.374[a]	.140	-.039	4.385
Trail stage	.551[a]	.303	.158	5.531
Adoption stage	.528[a]	.279	.129	5.332
Discontinues stage	.490[a]	.240	.082	4.310

a. Predictors: (Constant), KISF3, KISF1, KISF2, TSEF1, TSEF2

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

**Significant at the 0.05 level

Table 6:8: Model summary of regression analysis of FFS programme

Source: Author's own data (2015)

Coefficients[a,b] Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
Awareness	Constant	81.305	1.117		72.76	.000		
	Lack of knowledge and resources	-.722	.518	-.237	-1.39	.176	.937	1.06
	Lack of compatibility	-1.239	.713	-.311	-1.73	.095	.846	1.18
	Availability of extension services	1.323	.792	.283	1.67	.108	.949	1.05
	Poor information linkages	-.841	.708	-.200	-1.18	.247	.959	1.04
	Lack of reliable information source	.638	.706	.165	.905	.375	.821	1.21
Interest	Constant	59.75	1.799		33.22	.000		
	Lack of knowledge and resources	-.651	.834	-.154	-.781	.442	.937	1.06
	Lack of compatibility	.105	1.148	.019	.092	.928	.846	1.18
	Availability of extension services	-.819	1.274	-.125	-.642	.527	.949	1.05
	Poor information linkages	1.848	1.139	.315	1.622	.118	.959	1.04
	Lack of reliable information source	-.582	1.136	-.108	-.513	.613	.821	1.21
Evaluation	Constant	56.35	1.347		41.82	.000		
	Lack of knowledge and resources	.409	.625	.128	.655	.519	.937	1.06
	Lack of compatibility	.022	.860	.005	.026	.980	.846	1.18
	Availability of extension services	-.686	.955	-.140	-.719	.479	.949	1.05
	Poor information linkages	1.312	.853	.297	1.53	.137	.959	1.04
	Lack of reliable information source	.121	.851	.030	.142	.888	.821	1.21
Trail	Constant	57.142	1.699		33.62	.000		
	Lack of knowledge and resources	-1.896	.788	-.423	-2.40	.024	.937	1.06

	Lack of compatibility	1.151	1.084	.197	1.06	.299	.846	1.18
	Availability of extension services	-1.826	1.204	-.265	-1.51	.142	.949	1.05
	Poor information linkages	-.132	1.077	-.021	-.123	.903	.959	1.04
	Lack of reliable information source	.041	1.073	.007	.038	.970	.821	1.21
Adoption	Constant	45.623	1.638		27.84	.000		
	Lack of knowledge and resources	.026	.760	.006	.034	.973	.937	1.06
	Lack of compatibility	-1.523	1.045	-.274	-1.45	.158	.846	1.18
	Availability of extension services	-2.356	1.161	-.361	-2.03	.050	.949	1.05
	Poor information linkages	1.514	1.038	.258	1.459	.157	.959	1.04
	Lack of reliable information source	.647	1.035	.120	.625	.538	.821	1.21
Discontinues	Constant	15.380	1.324		11.61	.000		
	Lack of knowledge and resources	-.090	.614	-.027	-.147	.885	.937	1.06
	Lack of compatibility	-2.029	.845	-.464	-2.40	.024	.846	1.18
	Availability of extension services	-.367	.938	-.072	-.391	.699	.949	1.05
	Poor information linkages	1.237	.839	.268	1.47	.153	.959	1.04
	Lack of reliable information source	-.892	.836	-.209	-1.06	.297	.821	1.21

a. Dependent Variable: Awareness, Interest, Evaluation, Trail, Adoption , Discontinues
b. Linear Regression through the Origin

In bold fond are estimates significant at the 0.1 level

Table 6:9 : Factors constraining of FFS programme adoption

Source: Author's own data (2016),

Factors constraining for Yaya Programme adoption

Model Summary Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Awareness stage	.360[a]	.129	-.052	4.201
Interest stage	.364[a]	.133	-0.48	5.849
Evaluation stage	.261[a]	.068	-.126	4.565
Trail stage	.410	.168	-0.05	6.045
Adoption stage	.488[a]	.238	.079	5.483
Discontinues stage	.144[a]	.021	-.183	4.893

a. Predictors: (Constant), KISYF3, TSEYF2, KISYF2, KISYF1, TSEYF1

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

**Significant at the 0.05 level

Table 6:10 : Model summary of regression analysis of Yaya programme

Source: Author's own data (2016),

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
Awareness	Constant	80.288	1.299		61.80	.000		
	Economic and Environment barriers	-.421	.496	-.178	-.849	.404	.824	1.213
	Lack of Knowledge and Experiences	-1.317	.873	-.289	-1.50	.145	.990	1.010
	Lack of trust on Extension services	.116	.773	.030	.150	.882	.887	1.128
	Lack of Information and training	-.393	1.106	-.070	-.355	.726	.921	1.086
	Poor information link	.185	.851	.045	.217	.830	.856	1.168
Interest	Constant	60.55	1.808		33.48	.000		
	Economic and Environment barriers	-.731	.691	-.222	-1.05	.300	.824	1.213
	Lack of Knowledge and Experiences	-.166	1.215	-.026	-.136	.893	.990	1.010
	Lack of trust on Extension services	-.321	1.076	-.060	-.298	.768	.887	1.128
	Lack of Information and training	1.581	1.539	.203	1.027	.314	.921	1.086
	Poor information link	-.770	1.185	-.133	-.650	.522	.856	1.168
Evaluation	Constant	57.65	1.411		40.84	.000		
	Economic and Environment barriers	-.580	.539	-.234	-1.07	.292	.824	1.213
	Lack of Knowledge and Experiences	-.441	.949	-.092	-.465	.646	.990	1.010
	Lack of trust on Extension services	-.052	.839	-.013	-.062	.951	.887	1.128
	Lack of Information and training	.490	1.201	.084	.408	.687	.921	1.086
	Poor information link	.050	.925	.012	.054	.957	.856	1.168
Trail	Constant	51.95	1.869		27.79	.000		

	Economic and Environment barriers	-.779	.714	-.224	-1.09	.286	.824	1.213
	Lack of Knowledge and Experiences	1.244	1.256	.185	.990	.332	.990	1.010
	Lack of trust on Extension services	-1.055	1.112	-.188	-.949	.352	.887	1.128
	Lack of Information and training	.951	1.591	.116	.598	.555	.921	1.086
	Poor information link	1.976	1.225	.325	1.61	.120	.856	1.168
Adoption	Constant	45.393	1.695		26.77	.000		
	Economic and Environment barriers	-.850	.648	-.258	-1.31	.202	.824	1.213
	Lack of Knowledge and Experiences	.250	1.140	.039	.220	.828	.990	1.010
	Lack of trust on Extension services	-.348	1.008	-.065	-.345	.733	.887	1.128
	Lack of Information and training	-.760	1.443	-.098	-.527	.603	.921	1.086
	Poor information link	-1.868	1.111	-.324	-1.68	.106	.856	1.168
Discontinues	Constant	15.331	1.513		10.13	.000		
	Economic and Environment barriers	.057	.578	.022	.099	.922	.824	1.213
	Lack of Knowledge and Experiences	.636	1.017	.127	.625	.538	.990	1.010
	Lack of trust on Extension services	-.131	.900	-.031	-.146	.885	.887	1.128
	Lack of Information and training	.208	1.288	.034	.161	.873	.921	1.086
	Poor information link	-.150	.991	-.033	-.151	.881	.856	1.168

a. Dependent Variable: Awareness, Interest, Evaluation, Trail, Adoption , Discontinues
b. Linear Regression through the Origin

**Significant at the 0.05 level

Table 6:11 : Factors constraining for Yaya Programme adoption

Source: Author's own data (2016)

Chapter 7

Conclusion

Agriculture is the most important determinant of food security, economic stability, and social welfare for rural communities in developing countries. Consequently, it needs to remain sustainable through the proper maintenance of agricultural lands and to respond to environmental, economic, and social challenges such as climate change, rising food prices, and changes in consumer preference as well as attitudes. This requires efficient and well-functioning innovation systems, which includes knowledge adoption and the sourcing of private and public R&D institutes as well as universities. In addition to knowledge sourcing and generation, the system's effectiveness depends on its capacity to diffuse this knowledge among its members and potential end users.

In the context of agricultural innovation in developing counties, this task is closely linked to extension services. These establish bridges between researchers and farmers enabling knowledge to diffuse from the scientific sphere to where it is eventually utilised. Accordingly, the agricultural innovation system can be defined as networks of actors, organisations, and individuals, which within a specific set of agriculture-related institutions and policies, creates and utilises innovations (Klerkx et al., 2012). Put differently, the system comprises the processing of technological needs, the generation of solutions for these needs (by researchers), the dissemination thereof (by extension services), and finally the implementation of these solutions (by farmers).

The present thesis focused on one of these regional innovation systems in Sri Lanka. It analysed the role different actors play therein, their interactions, and how this relates to their effectiveness in terms of knowledge generation, diffusion, and utilisation. Particular attention

has thereby been paid to the role of the extension services that represent a central player in this system. The thesis consists of five chapters with distinct foci.

7.1. Impact of combinative capabilities on Absorptive capacity

The first chapter explored the role of R&D institutes in the context of a regional innovation system in a developing country. It identified the relative importance of the ACAP of R&D institutes for knowledge absorption and sharing. This also includes the quantification of the major organisational determinants of ACAP and how the latter shapes their innovation performance. More precisely, the chapter explained how the system, coordination, and socialisation capabilities of each matter for the acquisition, assimilation, transformation, and utilisation of external knowledge. By means of an empirical study, the chapter found that the adaptation of formalised rules by R&D organisations is significantly related to their abilities to acquire and exploit knowledge. In addition, routinised plans and procedures are also additive.

The empirical study reveals furthermore that participation in decision-making processes, which constitutes a determinant of coordination capabilities, supports knowledge assimilation processes. With sufficient coordination, intensive collaboration among different working groups of the R&D institutes (research teams, research planning teams, and research monitoring and evaluation teams) becomes possible, which helps in the realisation of research projects and the creation of new internal and external knowledge linkages. To some surprise, the empirical study did not find any of the variables representing socialisation capabilities to have a positive relationship with organisations' ACAP. In particular, the latter finding demands more attention in future studies.

In summary, this chapter confirms the relevance of some of the determinants of organisational absorptive capacity that have been put forward in the literature. It complements this research by extending the existing empirical evidence to the context of developing countries, which has received much less attention so far. Moreover, it adds further evidence on the heterogeneity of

R&D institutes in terms of their abilities to acquire, assimilate, transform, and exploit new external knowledge.

Nevertheless, there are several limitations of the study that may lead the way of future research. For instance, the data may suffer from a key informant bias, which could not totally be eliminated from the data. In addition, the empirical measurement of the different dimensions of absorptive capacity remains a challenge. The employed scales need to be further refined, developed, and elaborated upon in the future. Moreover, approaches need to be explored of how to adapt them more accurately to the context of agricultural innovation processes in a developing country such as Sri Lanka.

7.2. The network position and absorptive capacity

This chapter focused on the relationship between knowledge sourcing activities and the innovative capacity of (public) R&D institutes in Sri Lanka. The empirical study in the first part of the chapter confirmed that resource availability matters in as much as larger research organisations and organisations with higher levels of absorptive capacity tend to achieve more innovative output. It also revealed that specialised research organisations, i.e. those that focus on a particular thematic research area, perform better in terms of application-oriented research. Similarly, more diversified research organisations appear to have an advantage with respect to basic information. With respect to their knowledge sourcing, it was found that R&D organisations depend more heavily on formal than on informal knowledge sources for innovative activities. This is confirmed in the empirical analysis of chapter four in this thesis, which found that particularly formal knowledge sharing platforms are of importance in this context.

The second part of this chapter investigated the behaviour of R&D institutes from a network perspective. It thereby focused on the institute's centrality in the inter-organisational network of R&D institutes in Sri Lanka. It was argued that institutes occupying a *central* position in the network are more likely to access and share knowledge and information. The study adds to the literature by highlighting the variations in the roles research institutes play in these networks,

with some primarily functioning as ‘net knowledge sources’, while others rather collect, exploit, and utilise knowledge from other research institutes. The study discusses how this relates to some institutes acting as ‘gatekeepers’ in the network.

Based on the observation of significant variance in research institutes’ embeddedness in the knowledge network, the empirical investigation explored the implications of these differences for their innovative activities. Amongst other things, it was shown that in-degree centrality negatively relates to innovation performance in basic research. In contrast, out-degree centrality was shown to have a positive relation. Research institutes that intensively source knowledge from other institutes (in-degree centrality) are less innovative compared to institutes that serve as a knowledge source for others (out-degree centrality). It was argued that these insights signal that research organisations do not need to rely on external knowledge to be innovative, as they themselves are creators of knowledge. Some of the investigated organisations have been found to be more willing to share their knowledge with others, particularly via scientific publications.

Using a non-parametric correlation test, it has been shown that the influence of organisational absorptive capacity is helpful for securing a distinct position in the network. A primary example in this respect is the Postgraduate Institute of Agriculture (PGIA) that was identified as the primary connecting agent and ‘knowledge hub’ in the network. Its position is likely a consequence of its capabilities of conducting collaborative and multidisciplinary projects with other research institutes. PGIA primarily conducts and coordinates agricultural research for national agricultural requirements.

Nevertheless, there were a number of empirical research shortcomings that need to be kept in mind when interpreting these outcomes. For instance, the small sample size (29 institutes) might affected the statistical analyses. In addition, the cross-sectional nature of data is a challenge when performing an empirical analysis as it bears the danger of endogeneity. Consequently, it is suggested to use a multi-period survey and a continuous evaluation of the institutes to build a better empirical basis for future studies.

7.3. Motivations, Abilities and Opportunities and absorptive capacity

This chapter of the thesis concentrated on the application of the absorptive capacity concept to the individual level. More precisely, it identified the relevance of three individual factors (motivation, ability, opportunity) for the development of the AIs' absorptive capacity.

Individuals are considered the primary knowledge creators and key knowledge repositories in organisations. The competitive advantages of those organisations depend on the individual's specific abilities to exploit external knowledge in internal applications. However, these abilities differ across the individuals and most individuals are specialised in a particular task. Further, individual motivation is also crucial for the knowledge acquisition process. Despite the vast amount of literature on absorptive capacity, little research has been carried out on how an organisation's absorptive capacity differs in terms of an individual's abilities and motivational factors. Hence, this study aimed to fill this research gap with an empirical study on agricultural instructors in the agricultural advisory services in Sri Lanka.

Concerning individual ability, the chapter showed it to have a positive association with the knowledge assimilation and utilisation of AIs. Individual opportunities arising from socialisation mechanisms were also found to contribute to the development of an AI's absorptive capacity. This particularly applies to their capacities of knowledge assimilation and transformation. In contrast, no motivation was found to be associated with individual-level absorptive capacity.

Corresponding to the positive research findings on individual ability, Cohen and Levinthal (1990) and Yildiz et al. (2018) also have shown that individual ability is an antecedent factor of absorptive capacity that can contribute to individuals' learning performances. Furthermore, the positive impact of opportunity on absorptive capacity through social interactions was supported by previous research through the theory of social proximity (Broekel & Binder, 2007; Bathelt et al., 2004; Mäkelä et al., 2007; Argote et al., 2003; Boschma, 2005; Fritsch & Monz, 2010; Lagendijk & Lorentzen, 2007) and through social linkages and socialisation mechanisms (Breschi & Lissoni, 2009; Argote & Ingram, 2000; Minbaeva & Michailova, 2004; Minbaeve et al., 2007).

Additionally, the impact of individual motivations on absorptive capacity exhibited contradictory findings to the literature. According to Yildiz et al. (2018) and Amabile (1997), the motivation of an individual improves their willingness to recognise, assimilate, and exploit new external knowledge. Moreover, Vansteenkiste et al. (2004) show higher learning performances among intrinsically motivated individuals.

The study in this chapter suggested that a key managerial strategy for how extension organisations can improve their knowledge absorption performance is to more strongly encourage their employees through socialisation mechanisms. For instance, arranging more opportunities for AIs to interact with each other as well as with farmers appears to be an effective approach in this context. Their abilities can further be improved through effective human resources management including staff trainings and regular performance appraisals. In general, such helpful social interactions can be stimulated by providing communication opportunities, establishing team building activities, and knowledge sharing activities among major stakeholders of the agriculture innovation system.

There are a number of empirical limitations to this study. The research findings of the empirical analysis were based on 72 AIs in the Southern province of Sri Lanka. Consequently, they are rather limited in their generalisability. It is recommended that future researchers conduct analyses taking into consideration more diverse social and cultural backgrounds as well as work settings of AIs. The study also included a surprising observation: in the empirical analysis, the physical distance between farmers and AIs was shown to have a significant positive relationship with the knowledge assimilation process. Put differently, AIs perform better with respect to assimilating knowledge when their offices are further away from the farms they support, a clear topic for future consideration.

7.4. Accessing and using agricultural information and technology

This chapter investigated how paddy farmers in Hambantota district access and utilise agricultural knowledge and information. More precisely, its study aimed to explore the multiple

sources of information available to farmers and to analyse the farmers' adoption behaviours with respect to new technologies.

Farmers acquire information from multiple sources and knowledge about new technologies diffuses primarily through local social networks (Foster & Rosenzweig, 1995; Munshi, 2004; Bandiera & Rasul, 2002; Conley & Udry, 2010; Krishnan & Patnam, 2012). However, out of the multiple sources of information available to a farmer, whom to approach first for relevant information is determined by many factors. Similarly, farmers are links in a social network who seek the most trusted and reliable sources of information to adopt a new technology (Bandiera & Rasul, 2006; Magnam et al., 2015). Therefore, this study differentiated between the most frequent information sources and the most useful information sources, a distinction that has rarely been considered in the literature. Relatedly, farmers' adoption behaviours regarding new technologies were also explored.

The empirical results of the study confirm that farmers access and share information mainly through formal channels. This seems to be strongly driven by the high levels of trust they place in AIs, who they see as the most reliable information source. Consequently, local AIs are also perceived as the most influential actors when it comes to persuading farmers to adopt new technologies. While neighbouring farmers are also seen as an important information source for paddy farmers, they rank behind AIs. This has important policy implications, as it suggests that new technology promotion programmes can be easily implemented through this channel. Adding to this are the other findings of the empirical study: paddy farmers in Hambantota district are highly experienced and sufficiently literate to understand information about technologies introduced by the extension services. In general, the availability of sufficient information and healthy social relationships were found to be favourable factors for technology adoption by paddy farmers. Though these farmers in Hambantota district in Sri Lanka access information mainly through formal channels, related research has shown the trust in informal methods by farmers (Just & Zilberman, 2002; Conley & Udry, 2001, 2003). The information needs and information seeking patterns of farmers are location specific (Lwoga et al., 2010).

Lastly, the study found the majority of the farmers in Hambantota district to be early adopters who, while generally inclined to adopt new technologies, nevertheless want to see the outcome of a technological programme first, e.g. by other more innovative farmers in their area.

As with the other studies in this work, there are some empirical limitations that have to be kept in mind when interpreting the research findings. The cross-sectional nature of the data is a serious weakness. Ideally, adoption and diffusion processes should be studied with longitudinal or panel data, which is rarely available in the context of developing countries. Moreover, the employed measures to assess farmers' adoption behaviours were based on the perceptions of the farmers. While this has some advantages (more homogeneous answers and more objective assessment), it may nevertheless be subject to certain biases among AIs.

7.5. Factors Constraining Adoption of New Agricultural Technologies

This chapter explored the factors constraining the adoption of new agricultural technologies by paddy farmers. More precisely, a novel approach based on the AIs' perspectives has been used to identify constraints to the adoption process of two public technology transfer programmes: FFS and Yaya 2. Crucially, the study differentiates between two sorts of constraining factors: techno-socio-economic factors on the one hand and factors associated with knowledge and information sharing on the other.

The adoption of new and improved technologies is seen as a major factor in the productivity improvement in the agriculture sector (Munshi, 2004). Nevertheless, the adoption rate of new technologies has been and still remains low in most developing countries (Mwangi & Kariuki, 2015; Bandira & Rasul, 2002). There is a vast literature studying factors that determine the adoption of agricultural technology (Katungi & Akankwasa, 2010; Akuduguet et al., 2012; Loevinsohn et al., 2012; Adesina & Baidu-Forsen, 1995). Among those, economic, social, and institutional factors were considered as the first group of factors while farmers' access to knowledge of and about new agricultural technologies was the second prominent factor (Akudugo, 2012; Rogers, 1995). Even though many studies have investigated these factors, their

relative importance in the context of developing countries is still unknown, undoubtedly due to the limited availability of data. Therefore, this study attempted to fill this gap by means of empirical analysis.

The regression analysis of the study found that a lack of compatibility and a low availability of extension services are the major constraining factors in the adoption of technologies promoted by the FFS programme during the awareness, adoption, and discontinuation stages. In contrast, for the Yaya programme, no statistically relevant factors were identified. These results highlight that the two programmes differ substantially. Apparently, it is the individual set-up of such support programmes that defines how they will be adopted and what obstacles may limit their diffusion. This is crucial for the design of new programmes.

For instance, to overcome one of the most important constraining factors (lack of compatibility), the better adaptation of the programme to the true needs and situations of farmers will help its implementation. It also suggests that 'one-size-fits-all' approaches are insufficient, and more location-specific solutions should be sought after.

In this context, the FFS programme already includes a number of steps in the right direction. The programme facilitates learning through discovery and experimentation by linking the extension services to farmers. This can in principle help to solve the lack of compatibility between farmers' current practices and the demands of new technologies. In particular, collaborative activities of AIs and farmers will help to identify technologies that are most appropriate for the local context. Similarly, the programme promotes group cohesion and teamwork among farmers. Accordingly, the results suggest that the FFS programme functions as a social empowerment tool. However, this clearly needs further investigation in the future. In any case, policy makers and researchers need to obtain a better picture of the information needs of farmers by implementing a systematic needs assessment process.

Of course, there are a number of empirical limitations that may lead the way for further empirical research. The measures employed are based on the perception of AIs, which may again introduce some biases. For instance, to a certain degree AIs were put into the situation of evaluating their own effectiveness in terms of technology diffusion. This is likely to have introduced self-

perception and self-assessment biases. In addition, the empirical dataset only uses 30 interviews, which is very restrictive in terms of size and limits the application of more advanced statistical methods.

7.6. Summary and Conclusion

In summary, this dissertation explored the inner workings of a regional agricultural innovation system in the Hambantota district of Sri Lanka. In general, it was found that each actor of the agricultural innovation system has substantially specialised in generating and diffusing relevant agricultural technology. In particular, it was found that formal knowledge sources act as a complementary and synergistic pool of information for farmers. This has led to a remarkable degree of technology adoption in this rural area of Sri Lanka.

However, there still seems to be room for improvement. The research highlights that the existing interactions of researchers with other actors within the innovation system seems to be inadequate. Clearly, more collaborative activities promise additional benefits and should be explored in the future. Similar arguments can be applied to the system capabilities (formalisation and reutilisation) of research institutes that are still underutilised and underdeveloped.

As for the main focus of this dissertation, the role of AIs in the technology adoption process often seem to be inadequate when it comes to introducing new technology to rural farmers. Therefore, it is suggested to enrich the active intervention of AIs with respect to introducing new technologies to farmers. This particularly concerns their ability to provide relevant and comprehensive information on the usefulness of these technologies. Importantly, strengthening the present extension services is likely to enhance the productivity of the paddy sector in Hambantota district.

Another insight arising from this thesis is that R&D institutes in Sri Lanka are dominated by public bodies with rather limited private sector engagements. Even when private research organisations may have other research goals external to the immediate needs of local farmers, joint ventures

and private-public partnerships in research and extension services are underexplored and hold great potential for lifting the efficiency of the agriculture innovation system in Sri Lanka.

Lastly, the dissertation illuminates the general absence of adequate policy analysis in the context of developing countries and the agricultural sector. It represents a first step in this direction. Clearly, more research on policy intervention in agricultural innovation systems in developing countries is suggested. Moreover, a deep analysis of the three actors of the agriculture innovation system can be done through more advanced analytical approaches. For instance, a Triple Helix approach, as suggested by Ranga and Etzkowitz (2015), may serve as an alternative research framework. This will allow for an even more comprehensive investigation of the costs and benefits of the present agriculture innovation system and for the development of policy recommendations.

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- **Reading for the Final defense of PhD in Economic Geography,** Faculty of Natural Science, Leibniz University of Hannover, Germany.
- **2013 - Master in Agricultural Economics**, Faculty of Agriculture, Humboldt University, Berlin, Germany.
- **2011- Master in Agribusiness Management**, Faculty of Agriculture, University of Ruhuna, Sri Lanka.
- **2006- Bachelor in Agriculture Science (Hons) S**pecialized in Agricultural Economics & Extension Faculty of Agriculture, University of Ruhuna, Sri Lanka

Working Experience

1. **Lecturer** - Department of Agric. Economics and Extension, Faculty of Agriculture, University of Ruhuna. (From June 2008 to up to date).
2. **Temporary Assistant Lecturer**- Department of Agric. Economics and Extension, Faculty of Agriculture, University of Ruhuna. (from April 2008 June 2008)
3. **Temporary Research Assistant**- Department of Agric. Economics and Extension, Faculty of Agriculture, University of Ruhuna. (From April 2007 to April 2008).
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List of Publication

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10. **Silva, K.N.N, 2011,** Effect of management practices on the organizational performance: A case study of multipurpose cooperative shop (MPCS) in *Kamburupitiya*, proceedings of the 8th Academic sessions, University of Ruhuna, 2011.

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