Understanding the Impact of the Rice Research System in Thailand from an Innovation Systems Perspective

Chaniga Laitae

Propositions

1. The centralized research system in Thailand constrains the effective use of Innovation Systems approaches.
   (this thesis)
2. In a less developed research governance system, impact generation depends critically on individual actors.
   (this thesis)
3. Most of the available scientific information is unsuitable for policy-making in the context of developing countries.
4. The paradox of pursuing a Ph.D. is the incompatibility between perfection and realism.
5. Formalities decelerate the advancement of technologies and innovations in society.
6. The use of dating apps fosters self-branding strategy in real life.

Propositions belonging to the thesis, entitled

Understanding the impact of the rice research system in Thailand from an innovation systems perspective

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Thesis

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Chapter 1

General Introduction

1.1 Introduction

The growing realisation that agricultural innovation takes place in the context of an agricultural innovation system (AIS) marks a sharp difference from earlier thinking on the linear process of innovation to a more interactive process (Hall et al., 2006; Klerkx et al., 2012). The AIS is defined as a network of organisations, enterprises and individuals focussed on bringing new products, new processes and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge (Klerkx et al., 2012). In this thesis, the roles of the agricultural research system within the AIS concept are examined.

In light of this systemic thinking, the roles of agricultural research have been re-examined from having the central role in steering innovation to being an important element of an innovation system (World Bank, 2008; Anandajayasekeram, 2011). The shifts in the roles of agricultural research have implications for the agricultural research system, which include researchers and research organisations but also funders of research, research policymakers, research users and evaluators. It has also been recognised that research organisations and researchers can fulfil different roles in contributing to innovations. For example, researchers are likely to be involved in lobbying and advocacy activities that contribute to network and coalition formation around specific innovations (Basu and Leeuwis, 2012). Another finding also found that researchers have been described as 'system builders' (Hellsmark & Jacobsson, 2009) or 'innovation champions' (Shambu Prasad, 2006; Klerkx et al., 2010).

Given the different roles of research organisations and researchers contributing to the innovation, this has spurred new debates on evaluating the impact of agricultural research. The measurement of the impacts of agricultural research has often reflected linear ideas on innovation and rather narrow views on the role and contribution of research. It is recognised that the impact-generating process should embrace the multiplicity of actors and their interactions that contribute to the final impacts, through a variety of impact-generating mechanisms (Anandajayasekeram et al., 2009; Millstone

et al., 2010). Given the shortcomings of linear impact measurement approaches, alternative approaches for assessing societal impact of agricultural research have emerged to unravel the impact-generating process of various research projects and research organisations (see Joly et al., 2015; Spaapen and Van Drooge, L, 2011; Faure et al.). To understand research contributes to impact in complex settings, Douthwaite and Hoffecker (2017) suggest that impact evaluation needs to go beyond implementation at the project level but look at broader systems of production, trade, livelihoods etc., which is in line with the systemic outlook of the AIS approach to innovation.

In the context of developing countries, agricultural research plays a vital role in contributions to rural livelihoods, poverty alleviation, food security and economic growth in many developing countries (Walker et al., 2008). Investing in agricultural research is essential to generate and improve new technologies, crop varieties and production techniques. In recent decades, the private sector has played an important role in the development of technologies to increase agriculture productivity in the context of both developed and developing countries (Fuglie, 2016). However, it is observed that the private sector would invest few R&D resources into the countries where institutional arrangements providing intellectual property right enforcement, regulatory frameworks, technology dissemination, farm credit and marketing services are poorly developed (Pray and Umali-Deininger, 1998).

Southeast Asian countries, where agricultural research is predominantly funded by the public sector (World Bank, 2008), are characterised by variability in the functioning of the national agricultural research, education and extension system (Meredia and Raizer) in terms of its organisation and its connection with stakeholders. This is reflected in considerable criticism regarding poor functions in agricultural research systems, including weak linkages and synergies between actors in the research system, and lack of coordination with stakeholders in the innovation system are reported (Gijsbers and van Tulder, 2011). In the context of such weak institutional arrangements in developing countries, Faure et al. (2018) argue that researchers and researcher organisations can perhaps fulfil roles or functions that are usually fulfilled by other

actors in other contexts, which also correlates with the expanded perception of the roles of researchers alluded to earlier.

However, few studies have actually looked into whether and how researchers in developing countries respond to such weaknesses and indeed fulfil broader roles and functions. This dissertation aims to fill the gaps as regards how agricultural research contributes to the impact-generating process at the aggregate level using insights from the case study of the Thai rice research system. The study contributes to understanding the aggregate contributions of an agricultural research system in the impact-generating process from the different levels of the research system: the system level, the level of research programmes and the level of individual researchers.

1.2 Conceptual framework

The contributions of research are often highlighted as the generation of knowledge leading to tangible and intangible research outputs such as creating new technology, increasing the capacity for problem-solving, creating new industries or firms or forming networks and stimulating social interaction (Grossman et al., 2001; Salter and Martin, 2001). For agricultural research, conventional approaches to assess the benefit of research make measurements of the return on research investment without measuring and accounting for the research and innovation process (Hall et al., 2003). Rather than focusing on the measurement of input and output of research, a couple of concepts or approaches are introduced in this section to expand impact assessment to a more process-oriented approach (Hall et al., 2003; Springer-Heinse et al., 2003; Ekboir, 2003). This dissertation's conceptual framework is built on some broader concepts or approaches to unravel the process of impact generation, alluded to already in Section 1 and further expanded on in this section.

1.2.1. A shifting perspective from the national agricultural research system (NARS) to the agricultural innovation system approach (AIS)

In the past, agricultural research was conducted as a part of the national agricultural research system that tended toward linearity, with a movement of knowledge flowing

from clear producers of knowledge (researchers) to some end-users (such as farmers) through intermediaries such as agricultural extension (Spielman, 2005). The national agricultural research system (NARS) framework focussed on ways of optimising the investment in public research organisations and, later, public universities and extension services as a means of developing technologies to foster agricultural transformation and development (Spielman and Birner, 2008). This perspective has become gradually criticised, for example through approaches such as participatory research, farmer field schools and the farming systems approach, and this has led to the now dominant agricultural innovation systems approach (see for overviews, Röling, 2009; Neef and Neubert, 2011; Klerkx and Leeuwis, 2012).

The agricultural innovation systems (AIS) approach includes the farmer as part of a complex network of heterogeneous actors (e.g. input suppliers, processors, consultants, banks etc.) engaged in innovation processes, along with the formal and informal institutions (e.g. research funding, patent law) and policy environments (e.g. agricultural and innovation policy) that influence these processes (Hall et al., 2006; Klerkx et al., 2012). The heuristics of an innovation system helps to reconsider research as part of the larger, more complex and dynamic process of innovation (World Bank, 2006). Adopting an agricultural innovation system perspective has major implications for agricultural research in terms of a) adopting a more holistic perspective on agricultural innovation and b) reconceptualising research as part of the innovation process. The investment framework shifts to focus on linkages and incentives and on identifying where further organisational change is oriented to external responsiveness, in the form of interactive work with stakeholders in setting the agenda of research, knowledge co-production and an inter- and transdisciplinary approach to tackling complex innovation issues (Röling, 2009; Schut et al., 2014). These various research approaches, for instance the participatory approach alluded to above (see Neef and Neubert, 2009) but also sustainability science (Apetrei et al., 2021; Cash et al., 2003; Clark, 2007; Fazey et al., 2020; Wyborn et al., 2019), post-normal science (Funtowicz and Ravetz, 1993) and Mode-2 research (Gibbons, 1999, 2000), were introduced to make agricultural research more grounded in the context of reconciling the supply of

scientific information with the actors involved and the wider set of relationships in which research is embedded.

The applications of the AIS framework have been used in several studies to describe innovation processes in various aspects including the introduction of a given technology (Ekboir and Parellada, 2002), structural and functional development of innovation systems (Hekkert and Negro, 2009; Wieczorek and Hekkert, 2012; Hermans et al., 2015; Yang et al., 2014; Kebebe et al., 2015), different roles of actors in the innovation process (Klerkx et al., 2009; Hellsmark and Jacobsson, 2009; Turner et al., 2013; Lamprinopoulou et al., 2014) and organisational learning and change in research institutes (Hall et al., 1998). In this dissertation, these applications will be used and combined in the different chapters.

1.2.2. Contributions of agricultural research to impact generation process

The contributions of the research are often seen as the generation of knowledge leading to research outputs such as new technologies and innovations, research outcomes and impacts (Salter and Martin, 2001). However, over time this 'classical view' on what researchers do has become criticised (Schut et al., 2014; Wittmayer and Schäpke, 2014). Therefore, the diversity of impacts and the shifting roles of researchers and research organisations involved in the innovation process and in the generation of research impact have become an increasingly subject of study. The interactions between researchers and stakeholders are considered as main factors to produce relevant knowledge, its appropriation, diffusion, application and, finally, to create various kinds of impact (Joly et al., 2015; Spaapen and Van Drooge, 2011). To organise such an involvement, researchers can either play the role of facilitation of multi-stakeholder processes, or their research can be participatory and interactive, where the process itself is an 'intangible' output that leads to results and impacts. This change of roles and the importance of societal impact generation has also been noted for the agricultural domain (Röling, 2009) and for the rice sector in particular (Ciarli and Ràfols, 2019). The role of agricultural research plays in the AIS can thus be assumed not only to generate, translate and deliver technical knowledge to users: it also facilitates institutional changes and creates enabling environments for agriculture

(Botha et al., 2014; Botha et al., 2017; Dogliotti et al., 2014; Hall, 2008; Hall et al., 2001; Hall and Clark, 2010; Šūmane et al., 2018). Research, for example, plays an instrumental role in changing an existing policy or introducing a new policy, through research outputs such as policy briefs and advocacy roles that can create enabling environment within organisations (Schut et al., 2013).

Previous studies show that the interactions between the actors involved in the agricultural research system and in other domains (namely, farmer organisations, industry or policymakers) are factors that support key activities for the functioning of the AIS (Turner et al., 2013; Lamprinopoulou et al., 2014, Kebebe et al., 2015). These key activities and processes are labelled 'functions of innovations systems' (Hekkert and Negro, 2009). For research systems, the overall function means to develop, diffuse and utilise of new scientific and research management knowledge (Jonkers, 2011). The roles of individual researchers and research organisations as actors in research systems are also expanded to influence research and innovation system development and performance. For instance, research organisations play a role in the guidance of the search that can be done by formulating innovation agendas to create a vision and set priorities for an entire sector at a country or regional level (Turner et al., 2013), a role of facilitating the creation of a market for new technologies (Turner et al., 2013; Lamprinopoulou et al., 2014). This implies that researchers need to understand how they are part of an innovation system, i.e. their roles in the innovation process and the ways in which research and stakeholders (such as farmers and policymakers) are interconnected (Ragasa et al., 2011; Röling, 2009; World Bank, 2006).

Following this brief literature review with more in-depth literature reviews are done in the empirical chapters, the impact of research is generated in the following ways: a) based on the involvement of actors, b) at different stages and playing a variety of roles and contributing to different functions of the research and innovation system and c) following a non-linear process. As has been argued in the literature, these processes play out at and are influenced by different levels in the research system, such as the individual researcher, the projects they are in, and the organisational and overall

system context (Hall, 2001; Neef and Neubert, 2009; Klerkx et al., 2017). This multi-level context is also reflected in this dissertation.

This dissertation focuses on the roles of agricultural research in the impact-generating process using the rice research case study in Thailand. Figure 1.1 shows the visualisation of different levels of the rice research system on which this dissertation zooms in. The rice research system is seen here as a component of an innovation system in the rice sector. The three levels are: 1) macro-level, referring to the system of rice research; 2) meso-level, referring to rice research programmes; and 3) micro level, referring to the individual researchers. The scope of each chapter of the dissertation is organised according to three levels representing the topics that are approached in the dissertation.

1.3 Research questions and descriptions of the chapters

1.3.1 Research objectives and questions

The overall objective of this dissertation is to understand the processes through which the rice research system in Thailand contributes to the generation of societal impact. The rice sector is seen here as an AIS at the sub-sector level (Klerkx et al., 2012). The main research question that emerged from the knowledge gaps is: How does the rice research system perform as a component of an agricultural innovation system (AIS) to contribute to achieving societal impact through rice research? In relation to the main research question, this dissertation addresses the sub-questions that correspond with the chapters in this dissertation.

1. What are the key components, their linkages and the relations of the innovation system for Thailand's rice sector?

2. How has the rice research system in Thailand developed over time in terms of its structure, management and influence on the functions of the research system?

3. How do individual researchers engage in impact-oriented activities and what are the determinants for the engagement of the impact-oriented activities?

4. What are the roles of individual researchers as project/programme leaders in enhancing the impacts of rice research?

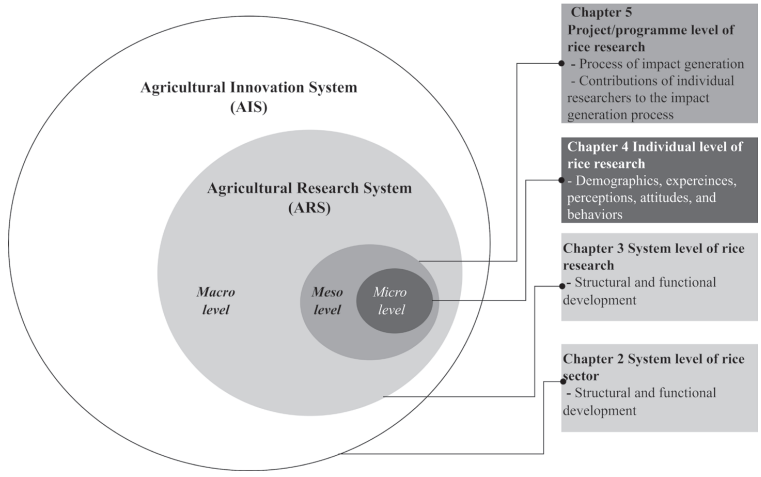

Figure 1.1 Scope of the studies

1.3.2 Description of the chapters

This dissertation is structured to link with the sub-research questions. The presentation of the chapters follows the multiple levels of the agricultural research system (ARS), as a component of an agricultural innovation system (AIS), which is mentioned earlier in Section 1.2 of conceptual framework (Figure 1.1).

Chapter 2 is aimed at understanding the innovation system of the rice sector in Thailand. In this chapter, the key components of the rice innovation system, their linkages and relations are presented.

Chapter 3 is anchored in the history of the rice research system in Thailand. This chapter further provides demonstrations of how rice research in Thailand governs at the system level. In this chapter, the chronological development of the rice research

system is described in terms of structure and management, and how it influences the function of development, diffusion and use of new knowledge (Jonkers, 2011).

Chapter 4 focuses on different engagements in impact-oriented activities and the individual factors, including demographics, attitudes, and perceptions, among individual researchers. This study contributes to emerging research areas with the aim of providing understanding of the perceptions and attitudes of influence actors in innovation systems. Reform and reorganisation have been implemented at the organisational and system level (Byerlee, 1998; Bin et al., 2013). The developments are rarely analysed in terms of the experiences of individual researchers (Ragasa et al., 2011).

Finally, Chapter 5 is related to the last research question and attempts to illustrate how individual researcher activities can contribute to impact generation through the innovation process. This chapter aims to contribute to the literature in unravelling the impact-generating process of research, including the roles of actors in the impact-generating processes.

1.4 Methodological designs

This thesis selected the rice research system in Thailand as the overall case study to explore the contribution of the rice research system to impact within the context in which it was located using a variety of data sources (Baxter and Jack 2008). A case study approach ensures that a phenomenon is viewed through multiple lenses which allows multiple facets of the phenomenon to be revealed and understood. It allows the researcher to explore individuals and networks, simple through complex processes, relationships, communities or programmes (Yin 2003). Different levels and processes in the rice research system were studied with different qualitative, quantitative and mixed method research approaches, including review of the literature, in-depth interviews and cross-sectional data survey. Data collection and analysis applied to answer each research question are described in Table 1.1 and further details are provided in the empirical chapters.

Question 1: What are the key components of an innovation system for Thailand's rice sector?

To demonstrate the overview of AIS in the rice sector, a literature review and in-depth interviews were conducted in order to obtain an overview of the business domain, research and education domain, and intermediate organisations in the rice sector in Thailand. Archival data were used, such as time series of rice production and trade from international sources, and literature and government documents related to policies and regulations in the rice sector were summarised. The data from primary and secondary sources were analysed based on content analysis. Codes were formulated to determine the key components and their interactions in innovation system for Thailand's rice sector.

Question 2: How does the rice research system in Thailand develop over time in terms of its structure, management and influence on the functions of the research system?

To answer this question, in-depth interviews were conducted in order to obtain: a) an overview of the development of rice research in Thailand so far, the organisations involved, policies related, research agendas and research executions and investment patterns; and b) the interactions among the actors of the rice research system. The in-depth interviews were conducted with purposively selected key informants including researchers from research organisations and universities, policy researchers, and directors of research organisations and funding agencies). All key informants were selected by the snowball sampling method (ref). As this research question covers the long period of the development of the rice research system in Thailand, the literature on rice research in Thailand was reviewed to explore the chronological development of rice research in Thailand in terms of organisational and technological development. The data from primary and secondary sources were analysed based on deductive content analysis. Codes were formulated to determine functional developments of the rice research system.

Question 3: How do individual researchers engage in impact-oriented activities and what are the determinants for the engagement of the impact-oriented activities?

To answer Question 3, a combination of in-depth interviews and an online questionnaire survey was applied. The in-depth interviews were conducted with the key informants being senior researchers in research organisations and universities. The online survey was conducted with researchers in public universities and public research organisations aiming at gaining information on the activities researchers conducted to impact orientation and the factors relating to individuals and organisations that determine different forms of engagement of researchers in impact-oriented activities. The data was analysed using descriptive statistics and multivariate analysis. An exploratory factor analysis (EFA) and a cluster analysis were conducted to identify groups of researchers based on researchers' activities. Finally, a regression analysis was conducted to determine which individual and organisation characteristics might explain the fact that researchers belong to different groups. Quantitative results were integrated with qualitative information to explain the influence of individual and organisation characteristics on research activities.

Question 4: What are the roles of individual researchers as project/programme leaders in enhancing the impacts of rice research?

The case study method was applied to provide a holistic understanding of the research contributions to the impacts of agricultural research. The research programme of rice research in Thailand was selected for case study. Data were collected from both primary and secondary data sources. The in-depth interviews were conducted with key informants from the research programme and stakeholders to obtain information on the contributions of researchers in the impact generation process. The secondary data was collected from research reports, scientific articles, publication databases and online documentation to obtain the information on the research programme. The data from primary and secondary sources were analysed based on deductive content analysis. Codes were formulated to determine the contribution of researchers to the impact generation process. The impact pathway analysis was applied to demonstrate activities research inputs, outputs, outcomes and impacts of the research programme.

Table 1.1 Overview of research designs per chapter

	Chapter 1	Chapter 2	Chapter 3	Chapter 4
Research question	What are the key components of an innovation system for Thailand's rice sector?	How does the rice research system in Thailand develop over time in terms of its structure, management, and influence on the functions of the research system?	How do individual researchers engage in impact-oriented activities and what are the determinants for the engagement of the impact-oriented activities?	What are the roles of individual researchers as project/programme leaders in enhancing the impacts of rice research?
Unit of analysis	Rice innovation system in Thailand	Rice research system in Thailand	Individual rice researchers in Thailand	Rice research programme
Descriptions	The main components of an innovation system in Thailand's rice sector	The structural and functional development of the rice research system in Thailand overtime	Researchers' engagement in the impact-oriented activities and the determinant of the engagements	Roles of individual researchers in generating impact of rice research
Data collection and sources of data	• Literature • Government documents • Policy documents	• Semi-structures interviews • Literature • Government document • Policy documents	• Cross-sectional survey • Semi-structured interviews	• In-depth interviews • Literature • Project documents
Data analysis	• Content analysis	• Historical analysis • Thematic content analysis	• Description statistical analysis • Multivariate analysis	• Historical analysis • Thematic content analysis

Chapter 2

Overview of Innovation System in Thailand's Rice Sector

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Abstract

The aim on this chapter is to provide insight into the broader innovation system context in the Thai rice sector which rice research is embedded based on the sectoral innovation system framework. Thailand ranks sixth among the world's top rice producers. Knowledge production has made important contributions to technological innovation in the whole supply chain of the Thai rice sector. This chapter presents the key components of the innovation system in the rice sector, namely market demand, business domain, research domain, intermediate organisations and infrastructure and framework conditions. The knowledge flow between the public research and business domain, especially smallholder farmers, is mainly found to be in the form extension programmes that are follow a linear model of knowledge transfer. The collaboration is enabled and facilitated by intermediate organisations such as government organisations and international agencies are found to be organised and playing an active role in bridging the research domain and business domain. Market demand has a strong influence on the Thai rice sector due to daily consumption of country's population and the role of Thailand in global rice market. The findings in this chapter help policymakers and stakeholders to understand the conditions and knowledge flows among the various domains in the Thai rice innovation system, and provide broader context to the chapters in this dissertation.

Keywords: Thailand; rice; sectoral innovation system; rice research; knowledge flows

2.1 Introduction

Thailand has become an important exporter of food crops, especially rice. Each year, approximately 55% of the total production is used for domestic consumption, while the remaining 45% is exported to the world market (Titapiwatanakun, 2012). This export trend has generated a large amount of income to Thailand. In prior studies, the rice sector has been recognised as a relatively innovative sector (Gijsbers and van Tulder, 2011) when compared to other commodities in the agriculture sector of Thailand. Knowledge has made important contributions to technological innovation in rice production (Jaroensathapornkul, 2007) and food processing, and has thus affected the whole supply chain of the rice sector (Thitinunsomboon et al., 2008). It is, therefore, of particular interest to explore interactions and activities of research and key actors within the rice sector in Thailand.

The sectoral innovation system concepts are applied in different sectors as it can help to understand and explain differential innovation dynamics across sectors in terms of the knowledge base, the actors involved in innovation, the links and relationships among actors, and the relevant institutions that shape interaction (Malerba, 2002). In the case of the rice sector in Thailand, the study by Thitinunsomboon et al. (2008) also applies the sectoral innovation system concept to the rice sector in Thailand to understand the emergence of innovative technologies on rice, exploring interactions and activities within the rice sector that support the technologies. However, in this chapter, the sectoral innovation system will be applied to understand the broader innovation system context of the rice sector and highlight on the knowledge flow between the domains as described in the Section 2. Then in Section 4, the key features composing the rice innovation system in Thailand are described, and in the final section the integrated picture of the innovation system in the Thai rice sector is presented in the discussion and conclusions.

2.2 The sectoral innovation system

A sectoral system of innovation concept of Malerba (2002) is defined as a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. The three building blocks are linked by interactions among firms and non-firms organisations. In this study, the key features composing the sectoral innovation system (SIS) are described using the principle domains proposed in Liu et al. (2015) (Figure 1). For the analysis of the rice sector in Thailand, the key components for the flow of knowledge in the rice sector is organised between the key components: 1) the market demand referring to the demand from global market and the market prospection for rice and rice products; 2) business domain with focus on farmers, rice millers and rice manufacturer; 3) research domain with focus on the public research including public universities and public research organisations, and research units in private companies that produce and transfer knowledge and new technologies; 4) the intermediate organisation that stimulate knowledge transfer between the domains; and 5) the infrastructure and framework conditions including the general views of policies, regulations and institutions related to technology development in the rice sector.

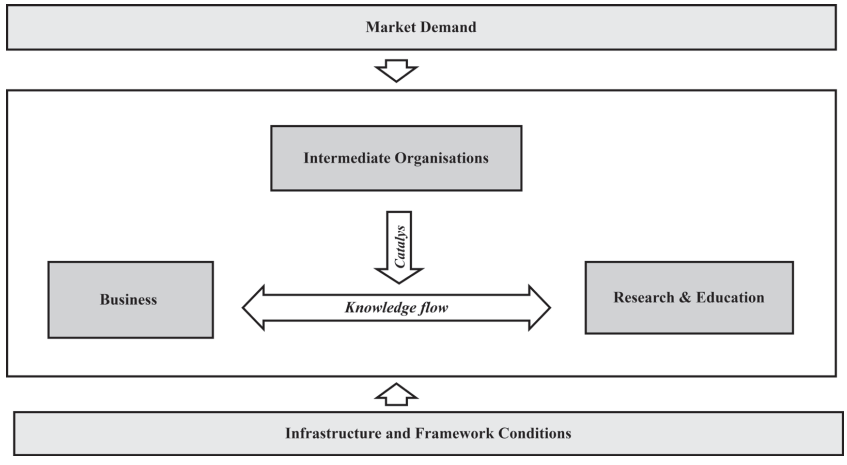

Figure 2.1 The main components of a sectoral innovation system.
Source: Liu et al. (2015)

2.3 Data collections and method

We applied different data collection approaches for the business domain, research & education domain, and intermediate organisations domain. Secondary data, such as scientific publications, research reports and governmental documents of rice in Thailand, were collected and summarised. The semi-structured interviews were also conducted with project managers, project analysts, researchers in public research organisations, a private company and international agencies to gain information from various stakeholders on the broad features of the innovation system of the Thai rice sector.

The next section provides the overview of Thailand's rice production, market trends, and the main domains in the sectoral innovation system, namely the business domain, the research domain and the intermediate organisations.

2.4 Result

2.4.1 Market demand

Thailand ranks sixth among the world's top rice producers. The total area devoted to rice amounts to approximately 9.0 million hectares, producing about 20-25 million tonnes of milled rice per year (Table 2.1). The main rice categories that Thailand exports are white rice, jasmine rice and parboiled rice. White rice is the most widely traded on global markets, accounting for 55-60% of all rice on world exchanges. Jasmine rice is a high-quality, high-price product by volume accounting for 12-14% of the rice traded on global markets which Thailand is the world's biggest exporter. Parboiled rice contribute a roughly 14-18% share of all world exports of rice (Sowcharoensuk, 2022). The majority of Thailand's rice production is devoted to the high-quality long grain rice, particularly jasmine rice. Jasmine rice was first developed in Thailand between 1949 and 1950 by breeding and selection of indigenous aromatic rice varieties and released to farmers in 1959 (Tanasugarn, 1998). In 2018, the prices of premium Thai jasmine rice reached a three-year high of 1,177 USD (FAO, 2018). Thailand has to put effort into maintaining a high-value added export sector for

aromatic rice, are aims to further boost the country's performance as world-leading rice exporter. However, Thailand's rice exports in 2020 dropped to the lowest level in 10 years (Table 2.2), as the tighter availabilities in rice stock and the strong currency reduces the competitiveness against other exporters (FAO, 2018).

Table 2.1 World milled rice production by country (million tonnes per year)

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
World	479.89	485.36	488.09	487.44	488.21	489.63	498.52	506.30	499.71	504.75
China	134.07	136.23	135.81	137.74	141.50	140.80	141.85	141.49	139.81	141.31
India	105.32	105.25	106.19	104.85	104.41	109.19	112.39	116.54	118.49	118.93
Indonesia	38.86	39.82	40.08	39.39	40.71	36.04	36.85	39.49	36.42	36.45
Bangladesh	33.77	33.68	34.37	34.55	34.55	33.65	36.12	36.30	36.41	36.62
Vietnam	28.28	29.17	29.37	30.00	30.08	28.76	28.52	29.38	29.01	28.52
Thailand	25.41	25.41	24.52	21.76	18.48	21.25	21.94	21.58	19.09	20.16
Americas	24.73	24.09	24.02	25.37	24.86	24.60	24.40	25.99	23.12	25.42
Myanmar	19.04	17.49	17.59	17.62	17.48	17.12	17.71	18.39	17.52	16.74
Philippines	11.13	12.03	12.30	12.65	12.11	11.76	12.86	12.72	12.55	12.87
Brazil	8.99	7.70	7.86	8.12	8.20	7.09	8.31	7.88	6.92	7.40

Source FAOSTAT (2021)a

Table 2.2 World rice exporter by country (million USD per year)

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Brazil	612.75	545.96	400.59	396.8	350.18	251.94	244.57	467.91	368.45	503.58
China,	426.96	272	416.67	378.28	267.18	378.81	596.17	887.31	1,058.98	916.64
India	4,081.41	6,129.24	8,205.31	7,905.65	6,380.08	5,315.53	7,075.76	7,346.17	6,800.67	7,980.03
Myanmar	337.41	152.91	157.91	621.31	631.05	438.94	1,030.82	921.75	782.43	773.18
Pakistan	2,062.02	1,878.33	2,113.52	2,199.64	1,927.20	1,703.05	1,743.50	2,001.81	2,270.30	2,101.27
Paraguay	85.1	117.79	165.38	177.58	129.83	196.01	193.99	219.23	226.65	295.01
Thailand	6,507.47	4,632.27	4,429.58	5,438.80	4,544.02	4,377.87	5,166.83	5,619.06	4,206.31	3,710.03
USA	2,087.30	2,075.29	2,176.32	1,992.28	1,993.15	1,821.50	1,718.14	1,690.93	1,877.04	1,888.78
Uruguay	472.05	560.07	507.99	513.12	361.42	413.85	459.36	394.00	375.82	461.56
Vietnam	3,656.81	3,673.65	1,673.96	2,936.93	2,807.90	2,159.98	2,634.59	2,621.44	2,434.25	2,790.95

Source FAOSTAT (2021)b

Market prospect of rice and rice products

Due to urbanisation and changes in consumption patterns towards convenience, food items such as ready-to-eat meals, rice, noodles, bakery, functional drinks and snacks, continue to grow (United State Department of Agriculture, 2021). In addition, trends toward more health-conscious eating has resulted in Thai consumers opting for innovative products that are seen to support well-being and health, especially beverages containing ingredients for immune, beauty, skin and brain boosting, weight-control, muscle building and health support. Products from brown rice and pigmented rice gain attention among domestic consumers given their potential to play a role in new health care products. Apart from the remarkable properties of many of the phytochemicals found in rice grain, rice is also non-allergenic and gluten free, making it a possible substitute for wheat in many areas of food and pharmaceutical product (Thitinunsomboon et al., 2011) (Table 2.3). The consumption and utilisation of the by-products of the rice milling process has increased, particularly using broken kernels (Triratanasirichai et al., 2017). Rice bran, rice husk, and broken rice have potential health, animal, and alternative food uses and can be profiled as waste reducing circular products. Rice bran, husk, and broken rice have a variety of applications for the mechanical, food, cosmetic, agricultural and fuel industries (Bodie et al., 2019).

Table 2.3 Potential of innovative rice products

Rice Products	Value Addition Potential	Market Potential
Baby foods	High	Medium/High
Modified starch	Medium/High	Medium/High
Rice bran oil	Medium	Low/Medium
Oryzanol	High	High
Probiotics	High	High
Ingredients for Cosmetics	High	High
Ingredients for Pharmaceuticals	High	High

Source Adapted from Thitinunsomboon et al. (2011)

The current climate and energy crisis strongly influence the potential of rice production in rice producing countries including Thailand. In addition, consumers' environmental consciousness strongly influences their attitudes towards their consumption behaviours (Connor et al., 2022). The rice products with special characteristics ranging from nutritional/health aspects to environmental aspects can respond to new market opportunities (see Table 2.3 and also Canavari et al., 2008).

2.4.2 The business domain

In the business domain, the three main groups of stakeholders in the Thai rice industry are farmers, millers and rice product manufacturers.

Farmers

In cropping year 2018, about 4.4 million households throughout Thailand produce rice (OAE, 20). Small-scale farmers that are majority of paddy farmers, are often confronted with a lack of access to resources including new knowledge and technologies (refXX). Thai rice farming is facing challenges such as high cost of production, deceleration of productivity, decrease in competitiveness in the global market, plant disease outbreak and labour shortages. The ability of small farmers to benefit from technological change is also restricted by factors, poor education and exchange of farming experiences, limited access to inputs such as seeds, sub-optimal control over the land and water supply (Suwanmaneepong et al., 2020), low household income, and limited exposure to trainings in relating to rice production technology (Joblaew et al., 2020). Many authors emphasise the need to strengthen farmers capacities, knowledge etc. (Kwanmuang), while other authors point to the strength of local knowledge and grassroots innovations to respond to challenges.

To strengthen farmers capacities, farmer organisations and cooperatives are formed within villages and sub-districts, and these are linked at higher administrative levels through farmer networks and higher-level organisations (United Nations Conference on Trade and Development, 2015). Basically, the farmers organisations also provide access to credit, inputs, joint marketing and agricultural extension services to members. In 2012, there were approximately 2,138 active rice farmer groups in

Thailand (Cooperative Promotion Department 2013a). A study by Kramol et al.(2020) presents two rice farmer groups established in Ubon Ratchathani province, Thailand namely, the farmer school group and the community rice mill group. Both groups were established to help members address specific problems related to production and market access for organic rice, and they organised involvement of farmers along the supply chain from farm to market, so that they are now producers, buyers, processors and sellers. The case of the these farmer groups shows the importance of fostering horizontal and vertical linkages to other groups and organisations within and outside the village, for instance government agencies, non-government agencies and the private sector.

Rice millers

Miller, a rice processors, is an intermediate segment playing an important role in a process to remove the husk and the bran layers to get edible rice. This process is considered as the most important value-added process for rice (Rerkasem, B, 2017). Thailand's rice mills can be classified by size into three groups: small-scale, medium-scale, and large-scale mills. The first group, which is the largest in terms of number, has a milling capacity of less than 12 tonnes per day. The second category has a milling capacity between 13 to 59 tonnes per day. The third group has capacities of over 60 tonnes per day (Naivikul, 2000a; Thitinunsomboon et al., 2011). There are about ten thousand rice mills located throughout the country. However, the majority of the rice mills are small-scale rice mills located in rural areas which are reported as inefficient and can only produce low quality rice at a relatively high production cost (Thitinunsomboon et al., 2011). About 900 large rice mills are developed and improved their technologies using new and high technologies both production and packaging lines. Many have attained GMP, ISO and HACCP standards. The quality of the rice which they produce and that have their own silos for the storage of rice often benefit for being within the same commercial network as exporters (Sowcharoensuk, 2022).

Rice product manufacturers

The rice product manufacturers are processing plants for producing a wide diversity of rice products such as vermicelli, rice noodles, crackers, rice bran oil and ready-to-eat meals located in many areas in Thailand. The study by Thitinunsomboon et al. (2011) reported that in parallel with the situation at the milling, about 91% of rice products processing plants are small in size, located in rural areas, and often using outdated equipment. However, a number of large factories have equipped with innovative equipment to meet export market criteria and some enterprises have invested in in-house R&D or collaborated with the public sector.

2.4.3 The research domain

Public research organisations and public universities

In Thailand, rice research is conducted at all stages of the value chain of rice by government agencies. Most of these come under the auspices of three ministries the Ministry of Agriculture and Cooperatives (e.g. Department of Rice (DoR)), the Ministry of Higher Education (e.g. public universities) and the Ministry of Science and Technology (e.g. the National Science and Technology Development Agency (NSTDA). Figure 2.2 presents the increase of research budgets allocated for rice research in 2008-17. The Ministry of Agriculture and Cooperatives has received more than 50% of the research budget following by the Ministry of Higher Education and the Ministry of Science and Technology, respectively. Rice research conducted by DoR mainly concentrates on farm technologies and variety improvement to improve farm productivity. A broad range of rice research is conducted by public universities especially those concerning new product development, postharvest technologies and variety improvement. The NSTDA intends to apply modern biotechnology to advance rice technology in Thailand (Toojinda and Lanceras-siangliw, 1991).

Private companies

A very few number of private companies conduct rice research. The rice product companies invest in in-house research towards commercialisation of innovative rice

products. For rice variety improvement research, in the past decade, there have been initiatives for hybrid rice breeding and hybrid rice seed production by multinational companies, namely Pioneer, Bayer, Syngenta, Pacific and a Thai-parent multinational company, Charoen Pokapand (CP) (FAO, 2010). Due to prohibitions in regulations related to imported rice germplasm for commercial purposes, Bayer has withdrawn the hybrid rice research programme from Thailand. CP is the only company that has engaged in research for rice genetic improvement, and successfully registered the first hybrid rice (Napasintuwong, 2017)

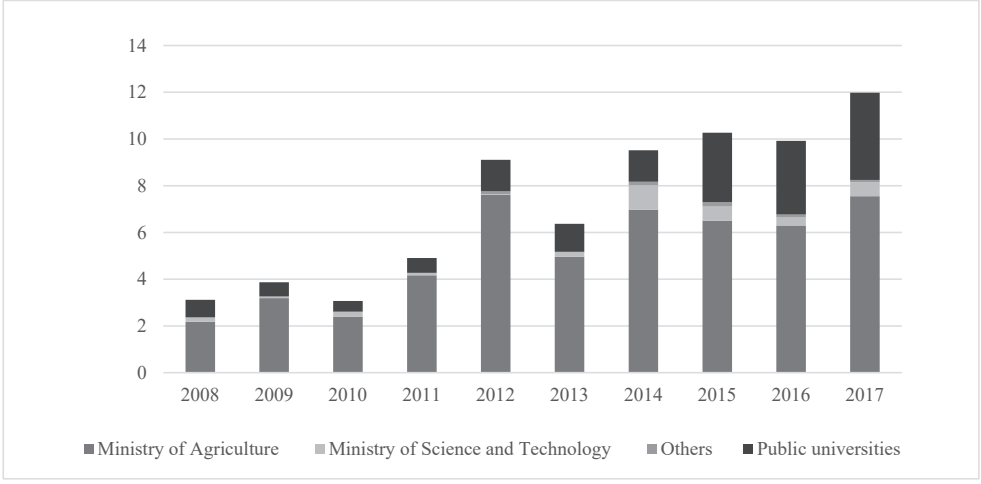

Figure 2.2 Research budget for rice research by research organisations/universities

Source: calculated from NRPM database (2008-2017)

Remark 1 USD = 31.50 Baht (March 2018)

2.4.4 The intermediate organisations

The roles of intermediary in the system of sectoral innovation and production in the Thai rice sector have been performed in different ways. The exchange of knowledge within the research domain is often facilitated by a close interaction between research actors, for instance the public universities and public research organisations, as well as through trainings and networks.

The knowledge dissemination to stakeholders in the business domain, especially farmers and small-scale millers is, mainly arranged in the classical knowledge transfer

model. The flow of knowledge is still largely in the linear form starting with research at the university and public research organisations, experimental stations and extension offices, to dissemination and practical implementation such as trainings programme and seed distribution systems. A growing realisation of increasing competitiveness in the rice sector has led to the recognition of the importance of close linkages between the key actors, and in connection with this some public research organisations have changed from the linear form of the knowledge transfer towards experimentation with new approaches. The NSTDA applies the so-called triple helix model (Chaisalee et al., 2015) to provide consultation in parameters optimisation, productivity improvement, loss reduction and training of workers in the local millers though its innovation and technology assistance programme (ITAP) and local universities (MOST, 2016)

Co-innovation and knowledge dissemination between research organisations and/or public universities and private companies is also facilitated via cooperative research programmes in which research organisations and/or public universities and private companies participate, facilitated and granted by the government agencies such as the National Innovation Agency (NIA) (Thitinunsomboon et al., 2011). This is expected to result in synergies derived from coordination and coherence between the business domain, research domain and intermediate organisations. One case exemplifying novel public and private partnerships and how actors perform their intermediary roles is the GABA rice project. The GABA rice project was initiated in 2007 by the Institute of Food Research and Product Development (IFRPD) and Kasetsart University to produce partially germinating brown rice which is an excellent source of gamma–aminobutyric acid (GABA). The project was granted by the National Research Council of Thailand (NRCT). The added value generated by GABA rice had the potential to bring increased benefits to all stakeholders, including farmers, mill operators, manufacturers, the university and ultimately the consumers. Later, technology transfer of GABA production to the private sector partners namely, Patum Rice Mill and Granary Public Company (PRG) and Tawatchai Inter Rice Co., Ltd. (TIR) was facilitated by the NIA and the Ministry of Science and Technology (Thitinunsomboon et al., 2011).

International agencies also play the intermediary roles in facilitating, participating and managing network with actors from different domains. For instance, the German Technical Cooperation (GTZ) launched the Thai Rice NAMA project, as part of the Better Rice Initiative Asia (BRIA) cooperating with the DoR and the private companies, namely Olam group and UTZ, to promote sustainable rice farming practices for farmers. The project supplies information for problem-solving and responding to farmers' needs develops capacity building programme for farmers and local government staffs on low-carbon and sustainable rice farming practice, and implements an area-based market strategy and model for low-carbon technologies.

2.4.5 Policies, regulations and institutions related to technology development on rice in Thailand

In general, the policies related to the rice sector in Thailand mostly are translated and formulated from the national development plan. A five-year rice policy and strategy has been prepared jointly by the Ministry of Agriculture and Cooperatives and the Ministry of Commerce (Thitinunsomboon et al., 2011; Paopongsakorn, 2019) to enhance rice production, promote rice export markets and solve rice problems. According to the government document, the Thailand's rice strategies are oriented to enhancing rice productivity at all stages of rice value chain, including management and development of farm production technology, postharvest and product development, improvement of marketing systems and logistics and supporting farmers' livelihood (Thitinunsomboon et al., 2011). In addition, Thailand has a strategy towards adding more value to agricultural products, including rice products (e.g. noodles, crackers, rice drinks), supplement foods (e.g. oryzanol, probiotics) and consumer goods (e.g. cosmetics) (Napasintuwong, 2019). The strategy towards value adding includes the promotion of organic products in both local and export markets. In tor order to address environmental challenges, an organic agriculture policy in Thailand was included in the national agenda and was later set up as the National Strategic Plan for Organic Agriculture Development (NESDB, 2008; OAE, 2013). The Thai Government encourages organic rice farming practices through financial and technical supports for the participating farmers. However, organic rice production in

Thailand is reportedly not very successful yet due to the lack of institutional capacity, a lack of coordination and cooperation between relevant agencies, and inconsistency in policies (Lee, 2021).

The existing research policy is in line with the above policy objectives, and hence supports research activities geared towards adding value to agricultural products and managing resources for sustainable agricultural growth (Suphannachart, 2015). The recent rice policy and strategy (2020-2024) has been developed through an integrative process between the Ministry of Agriculture and Cooperatives and Ministry of Commerce together with relevant stakeholders including rice farmer associations, rice traders and rice millers. The rice policy focuses on 1) strengthening farmers and farmer organisations for self-reliance and having enough income and well-being, 2) increasing the efficiency of rice production management and efficiency of competitiveness and 3) increasing the potential of research in rice breeding and rice production technology (Buddaboon et al., 2022). Although knowledge production and technology development are emphasised as ways to maintain the competitive advantage of Thai rice in global market, it is relevant to note that the new integrated policy contains no specific rice research agenda (Paopongsakorn, 2019) on how to respond to changing global market conditions.

The regulations related to rice research mainly focus on protecting and controlling rice germplasms and species (Napasintuwong, 2017). Thailand's Plant Variety Act (PVA) or seed law was enacted as a means to promote agricultural development and it regulates that all imports, exports, collections and transits of controlled seeds (including rice seeds) require a permit (Lertdhamtewe, 2015; Napasintuwong, 2017). For research purposes, rice seeds can be requested for approval by the Department of Agriculture (DOA). Therefore, foreign companies have no longer invested in rice breeding in Thailand (Napasintuwong, 2017). The intellectual property right system, including patent protection, trademarks, certification marks, and geographical indications (Tanasugarn, 1998) are mainly applied in the rice sector in the light of promoting quality of Thai rice in market. In the rice sector, the government support

technology dissemination between public and private sector mainly via research grants (see also Chapter 3).

2.5 Discussion and conclusions

The key actors and their characteristics of each domain as derived from this analysis are mentioned in the innovation system in the Thai rice sector diagram (Figure 3).

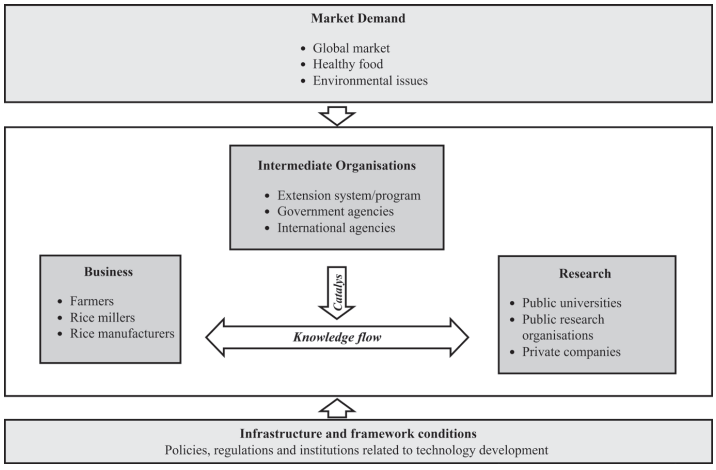

Figure 2.3 The innovation system in the Thai rice sector.

The knowledge flow between the public research and business domain especially, smallholder farmers is mainly found to be through extension programmes that follow a linear model of knowledge transfer. Collaboration in the system is enabled and facilitated by intermediate organisations such as government organisations (e.g. the NIA) and international agencies (e.g. GTZ), and these play an active role in bridging the research domain and business domain. The findings on intermediate organisations in the rice sector indicate that they perform multiple roles in knowledge and innovation intermediation (see Yang et al., 2014) to navigate the knowledge flow in the rice sector. In the case of GABA rice, the NIA plays roles in facilitating stakeholder partnerships between research and rice manufacturing by identifying the potential enterprises and providing funding sources for establishing product development at the industrial scale. In the case of the Thai Rice NAMA project, GTZ implements

policies on sustainable production in the rice sector along the rice value chain in cooperation with private companies, public research organisations and local farmers.

Market demand has strong influence as rice is an important component of daily consumption patterns, and because it plays a vital role in Thailand's socioeconomic development strategy. Global market demands are shifting towards healthy food and environmentally friendly production, and these trends have been translated to rice policies and strategies. Due to the absence of central policy and institutional mechanism to direct, support and ensure the effectiveness and cohesion of research activities in Thailand; however, there may remain gaps between knowledge generation at public research institutes, and the demands of the business domain and the global market.

In summary, the organisation of knowledge flows between the domains in the rice sector innovation system in Thailand continues to be dominated by a linear knowledge flow from research to extension. Intermediate organisation plays a limited role in promoting technological change and development through more interactive and integrated public-private partnerships. There appear to be possibilities to enhance the synergies between the research domain, business domain and intermediate organisations through inter-organisational collaboration, expansion of formal linkages and the creation of more coherence in research policies.

Chapter 3

Evolution of agricultural research systems in developing countries: A functionalist approach applied to the rice research system in Thailand

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Abstract

Agricultural research systems (ARSs) have been developed in many countries to respond to societal challenges, such as environmental degradation, food security, climate change, and market liberalization. ARS evolution has generally been reflected in changes in structure, management, and governance at different levels. Using the case of ARS in Thailand's rice sector, we aimed therefore to examine the evolution of an ARS in terms of functional development. The results show that the Thai rice research system has gradually developed in terms of structural characteristics and functions in response to the evolution of technological paradigms. The analysis indicates primarily that structural components of the research system have developed in line with functional needs and that the functions reinforce one another. This suggests that, apart from structural development, the rice research system should focus on institutional arrangements, with the aim of improving the efficiency and the effectiveness of public research, including decentralization of public sector decision making and resource allocation, and facilitating participation by a broad range of actors.

Keywords: rice research, agricultural research system, functionalist, Thailand

3.1 Introduction

After the Second World War, many countries developed formalized agricultural research systems (ARSs) (Fuglie et al., 1996; Janssen and Braunschweig, 2003; Spiertz and Kropff, 2011). According to the Green Revolution literature, in the 1970s and 1980s agricultural research focused on increasing agricultural productivity in developing countries to ensure food security and alleviate poverty, and the adoption of production technologies resulted in high-yield varieties of staple crops (Hazell, 2010). In the 1990s, many countries prioritized natural resource management and environmental preservation on their agricultural research agendas (Byerlee, 1998). The experience of the global food price crisis in the last decade refocused the conversation between agriculture and food security – and in particular the role of research – with renewed calls to examine the future of food systems in the context of shifting trends in commodity price volatility, climate change, and population growth (Stephens et al., 2018). In this view, agricultural research should embrace the entire food system and its transformation, not just the production stage, and focus on the agricultural production system: processing, logistics, and wholesaling must be included (Reardon et al., 2019). Societal challenges such as environmental degradation, food security, climate change, and market liberalization require agricultural research to shift from a mere focus on supply to a focus on downstream impacts on relative food prices, consumption, nutritional outcomes, and food security overall (Pinstrup-Andersen, 2000; Stephens et al., 2018).

In parallel with changes in focus and scope, ARSs have also been subject to increasing systemic changes in terms of governance, management, and connections with the agricultural systems and supply chains to which they are linked (Janssen and Braunschweig, 2003). Since the 1980s, in parallel with the stagnation of investment in public research, new institutional settings for ARS have emerged in many countries, with a diversity of organizational arrangements, such as public–private partnerships and competitive funding arrangements (Byerlee, 1998; Roseboom & Rutten, 1998; Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004 et al., 2004). Broadly similar challenges in relation to ARSs are faced not only in developed countries such as the

USA, Australia, Switzerland, the Netherlands, and the United Kingdom (Janssen and Braunschweig, 2003; Roseboom & Rutten, 1998), but also in many developing countries (Janssen and Braunschweig, 2003). Their responses to these challenges in terms of their organizational structure and financial management have been studied (see Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004; Sumberg, 2005; Gijsbers and Tulder, 2011). However, earlier studies often have not fully grasped how changes in structure, management, and governance are possibly related to, and affect, the operations of the research system in terms of functions fulfilled by the system, such as development, diffusion, and utilization of new knowledge, and, in turn, how these functions affect structural aspects.

This study aims to fill this gap by investigating the evolution of research systems in terms of structure, management, and governance, whether and how this evolution is influenced by the functions that the research system performs, and vice versa. We do this by applying Jonkers' (2011) framework focusing on the functionality of research systems, which draws on the functional approach to innovation systems (Hekkert et al., 2007; Bergek et al., 2008) and allows us to capture the interplay between structural characteristics and the dynamics of the research system in terms of seven key processes – or functions – in the development, diffusion, and utilization of new knowledge (Bergek et al., 2008; Jonkers, 2011). The functionalist analytical framework is applied to a qualitative case study in the rice research system in Thailand, where rice research has made important contributions to technological innovation and encouraged the growth of rice productivity (Gijsbers and Tulder, 2011; Jaroensathapornkul, 2007; Suphannachart, 2013). The main question guiding the analysis is therefore: how did the rice research system in Thailand evolve over time in terms of its structure, management, and governance, and how did this evolution influence the functions of the research system and vice versa?

The paper is structured as follows. Sections 3.2 and 3.3 present the conceptual framework and methodology. Section 3.4 illustrates the chronological development of the Thai rice research system in three development phases. The functions of the rice research system in the identified phases are mapped in section 3.5. The discussion is

presented in section 3.6. Conclusions and policy implications are presented in section 3.7.

3.2 Conceptual framework: functions of the agricultural research system

This study focuses on ARS as a component of the agricultural innovation system to generate, diffuse, and utilize knowledge and technology of economic value to the agricultural sector (Sumberg, 2005). An ARS is composed of agricultural research organizations and institutions and the relations or interactions between them (Figure 3.1). Universities, public research centres, private companies, funding agencies, and international agencies (funders, regulators, producers, and consumers of research-based knowledge and technology) represent the ARS organizations or actors. Institutions shape, and are shaped by, the actions of the organizations and the relations between them, in terms both of formal rules and regulations, such as R&D policies and intellectual property (IP) rights, and of informal beliefs, practices, and values (Edquist, 2001; Vanloqueren and Baret, 2009). Dynamics of global markets, public policies on agriculture and economic development, regulations, and consumers' needs influence the ARS even though they operate outside the boundary of the system. The ARS is embedded within a broader innovation system, including all the actors that contribute to innovation, even in innovation activities that are not concerned with research-based activities.

The availability of research infrastructures (e.g. labs, scientific equipment), the presence of highly skilled manpower, and a suitable supporting organizational structure are crucial conditions for the generation of new scientific knowledge. Operational structure translates into a public research system divided into four main levels: the operational level of research groups; the organizational or management level; the strategic level of research-funding organizations; and the policy level of government actors (Jonkers, 2011).

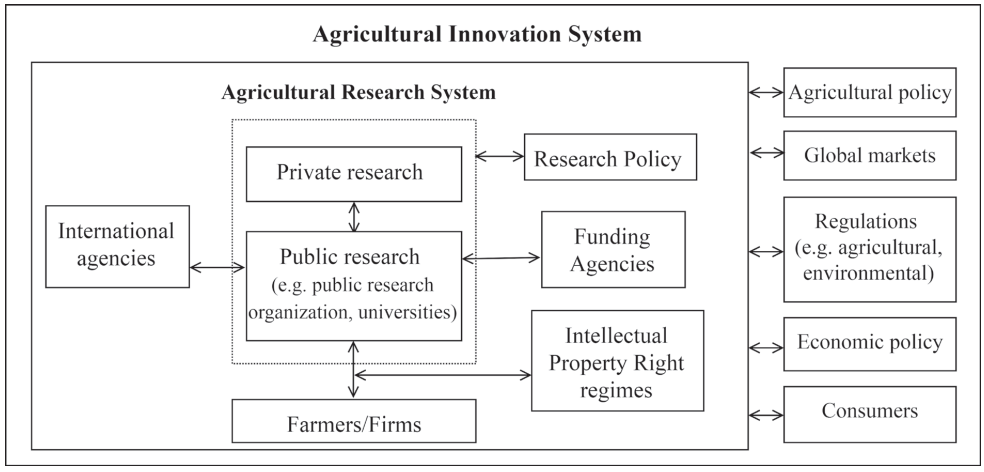

Figure 3.1 Components and structure of an agricultural research system within an agricultural innovation system

Source: Adapted from Vanloqueren and Baret (2009)

Different actors and focuses can be distinguished at each level, yet they are all interrelated (Van der Meulen and Rip, 1998). According to the literature on functional analysis of innovation systems, functions (i.e. the outcome of a number of processes in the innovation system) are highly important for well-performing innovation systems (Hekkert et al., 2007; Bergek et al., 2008). A functional approach implies a focus on the dynamics of key processes realized in the system rather than on the dynamics of structural components only (Bergek et al., 2008). In order to compare national research systems at different points in time, Jonkers (2011) translated this innovation system approach to the level of the research system. This *functions of the research system approach* aims to capture the structural characteristics of a research system, its dynamics, and the dynamics of a number of key processes that directly influence the development, diffusion, and use of new scientific knowledge in that research system. To analyse the transformation of a research system, Jonkers (2011) identified seven key functions that often overlap and influence one another: influencing the direction of research, organizational variation and novelty creation, resource allocation and dominant funding mode, diffusion of knowledge within the research system, diffusion

of knowledge to non-scientific users, evaluation procedure, and international orientation. We now briefly describe these functions.

Locus of control on the direction of research: The direction of research is related to priority setting, which aims to ensure that the resource allocation to research is consistent with national objectives and users' needs. This function refers therefore to research activities that can positively affect the visibility and clarity of specific needs for further research. The needs for further research can be prioritized at the different levels of a research system, in between these levels, and within research organizations (OECD, 2003).

Organizational variation and novelty creation: The creation of new knowledge is related to the availability of research infrastructures, the presence of highly skilled human capital, and a suitable organizational structure that supports and promotes the generation of new scientific knowledge (Jonkers, 2011). In addition, the inclusion of a wider range of organizations that can potentially participate in research funding and execution (e.g. other ministries, universities, non-governmental organizations, and the private sector) enhances the quantity and quality of financial and human resources (Byerlee, 1998). Recently, organizational and management models adopted in public research organizations have changed significantly in order to strengthen the efficiency and the effectiveness of research; for instance, a research management structure has emerged in which decentralized units in charge of execution interact in a crosscutting mode with various institutional programmes (Bin et al., 2013).

Resource allocation and dominant funding mode: Public funding mechanisms for research have evolved in many countries, moving away from providing block grants towards more competitive and contractual arrangements, which – although more costly to manage – are likely to improve the allocation of resources and allow for a successful transition towards greater efficiency and responsiveness to demands (Byerlee, 1988; Roseboom & Rutten, 1998; Huang et al., 2004). Competitive mechanisms for project selection have been introduced in many agricultural research organizations to ensure that research projects effectively meet users' needs and enhance accountability (Bin et al., 2013). However, to guarantee the transition, the funding mechanisms must be accompanied by a long-term strategy for research areas and priorities, a well-

articulated balance between strategic and applied research, and adequacy of both core and operational funding (Rajalahti et al., 2005).

Diffusion of knowledge in the research system: This function depends on the nature of the network and the mobility within and between research organizations, and on the collaboration and the training of new scientific manpower (Jonkers, 2011). It relates to the organizational structure of the knowledge network, primarily facilitating information exchange. Because of the growing complexity of science, research organizations need to develop partnerships to be able to access complementary skills and to participate in national and international research networks that promote an exchange of knowledge – among both partners and networks (Byerlee, 1998). Knowledge diffusion can take the form of workshops and conferences devoted to a specific technology topic.

Diffusion of knowledge to non-scientific users: Public ARSs have developed structures and mechanisms to implement activities for technology transfer through the agricultural extension service or indirectly through publication and media channels. Institutional arrangements – such as cooperative research agreements, patent licensing, and research consortia – have proved useful for increasing knowledge transfer to non-governmental institutions or private companies (Fuglie and Toole, 2014). In addition, providing researchers with guidance on IP protection and management of IP rights, and also encouraging entrepreneurship in research organizations, are addressed as key management practices that can facilitate knowledge or technology transfer to a variety of users (Bin et al., 2013; Huang et al., 2004).

Evaluation procedure is a function aimed at assessing knowledge claims through scientific quality criteria or – in some research areas – contributions to non-scientific objectives (Jonkers, 2011). In general, evaluation procedures take place at two operational levels. At the project level, the evaluation procedure is part of competitive mechanisms for resource allocation in the form of both ex-ante and ex-post impact evaluation (OECD, 2003; Bin et al., 2013). At the organizational level, evaluation (e.g. through a national research evaluation system or the use of publications and citations

as metrics) represents a policy tool to steer, manage, and improve the activities of, and investments in, research organizations (OECD, 2003).

International orientation is defined as the openness of a research system to the global scientific community (Jonkers, 2011). Over the last decades, international cooperation has gained crucial relevance for ARSs in developing countries, especially in the form of financial and technical assistance. International cooperation is critically dependent on the capacity-building ability at the national ARS level (World Bank, 2012). Various approaches have been integrated in national strategies to engage in international cooperation; for instance, a growing investment in human resources, sponsoring researchers or students to study or train abroad (Byerlee, 1998; Mruthyunjaya & Ranjitha, 1998), or the establishment of new organizational structures such as national centres of excellence (Byerlee, 1998; Jonkers, 2011).

3.3 Data and methods

This study examines the evolution of an ARS in a developing country through the functions of the research system approach. The rice research system in Thailand was selected as a case study to reflect the adaptations of an ARS to external challenges such as the shift in trends in commodity prices or global challenges such as environmental degradation, food security, and climate change (Stephens et al., 2018), and to internal challenges in terms of research governance and management. In this study, rice research comprises all kinds of public and private research activities conducted at all stages in the rice value chain (Thitinunsomboon et al., 2008). It includes agricultural research, biological science, agro-industrial research, as well as economic and social science research. The sources for the analysis of the transformation of the rice research system are manifold, to also allow for triangulation: in-depth interviews conducted in 2017 with senior researchers (13 interviews), policy analysts (7 interviews), and directors of research units (2 interviews) in research organizations, funding agencies, universities, and private companies; an analysis of policy documents of public authorities, such as the National Research Council of Thailand (NRCT), the National Science and Technology and Development Agency (NSTDA), the Agricultural

Research and Development Agency (ARDA), and the Department of Rice (DoR); and a multidisciplinary scientific literature review. The content analysis is based on coding interview transcriptions and relevant documents using the theoretical framework as the coding structure.

The results of the analysis allow us to disentangle the structural and the functional development at the different levels of the research system, using, on the one hand, evidence and experiences of researchers, policy analysts, and project managers derived from the in-depth interviews, and, on the other hand, deductive reasoning derived from results and conclusions in scientific publications and policy documents.

3.4 Results

In this section, a systematic analysis of the development of the rice research system is presented by mapping the functions performed by it in each of the three periods in which the development is studied.

3.4.1 The chronological development of rice research in Thailand

Thailand has consistently sustained its position as the world's biggest rice exporter thanks to considerable public investments in rice research (Thitinunsomboon et al., 2008), which focused mostly on improving rice production through agricultural technologies and management practices (Jaroensathapornkul, 2007). In particular, the Green Revolution technologies had dramatic and widespread impacts on the rice sector (Jaroensathapornkul, 2007; Isvilanonda and Bunyasiri, 2009). The development of rice research in Thailand can be analysed over three chronological phases, each characterized by institutional and organizational changes.

The initial configuration of Thai rice research

Rice research in Thailand started officially in 1916 when the first rice research and experiment station was established under the Department of Agriculture (DoA). In 1938, the Rice Division was established under the DoA to support rice production and seed multiplication programmes (Department of Rice, 2011). The first rice-breeding

programme began in 1950, with support from the United States Department of Agriculture (USDA) (Pochanukul, 1990). It marks the official start of the first research phase in Thailand (here called the formative phase) (FAO 2011).

After the first rice breeding programme started, the Rice Division, which was later upgraded to the DoR, had responsibility for rice research and extension. However, consequent to organizational adjustments of the DoA in 1973 and 1982, the organizational structure of the DoR changed, and it was downgraded to Rice Division again. The changes in institutional arrangements resulted in improved authority for the local rice research and experimental stations under the Rice Division (Pochanukul, 1990).

International agencies started to support Thai rice research, including the Rockefeller Foundation, the USDA, and the pre-eminent agency in rice research – the International Rice Research Institute (IRRI) – which provided funding, capacity building, and collaborations (FAO, 2011; Isarangkura, 1986; Pochanukul, 1990). The foreign support also facilitated the building up of Thai research personnel through education programmes for Thai students to study abroad. A number of Thai students received dedicated grants to study master and doctoral programmes abroad in several disciplines related to rice research. The lecturers and researchers who returned from abroad brought with them strong research skills and maintained their orientation towards the international scientific community.

Biotechnology and molecular biology in Thai rice research

From the 1980s, Thai rice research became more active in breeding programmes (Napasintuwong, 2018). Biotechnology and molecular biology were applied to develop disease resistance and improve quality and gradually contributed to increasing rice yields (Redoña E. D. 2004; Toojinda & Lanceras-Siangliw, 2013). This rapid rise in technology use was enhanced by the lecturers and researchers who acquired strong scientific skills abroad and by their continuing connections with foreign universities and research institutes.

One of the most remarkable milestones in biotechnology research in Thailand was the establishment of the National Centre for Genetic Engineering and Biotechnology (BIOTEC) within the Ministry of Science, Technology, and Innovation (MoST) in 1983, which later became part of the National Science and Technology Development Agency (NSTDA) (Damrongchai, 2002). The rice biotechnology programme was first launched by BIOTEC in collaboration with the Rockefeller Foundation in 1985. In 1998, BIOTEC joined the International Collaboration for Sequencing the Rice Genome (ICSRG), allowing Thai researchers to directly access the rest of the genome sequence made available by the other collaborating members (Damrongchai, 2002). In 2005, the gene responsible for making rice aromatic was discovered by the Rice Genome Project, and subsequently a gene patent was issued. With strong competency in biotechnology, BIOTEC became recognized as the main agency in rice biotechnology, and this recognition gave a boost to collaborations with public research agencies and universities (Napasintuwong, 2010; Toojinda and Lanceras-Siangliw, 2013). Besides being active in research, BIOTEC and the NSTDA provide research grants for biotechnology research and training programmes for public research organizations and universities. The emergence of new technologies in rice research as a consequence of the development of BIOTEC overshadowed the Rice Division, which carried out mainly conventional breeding programmes, and increased the competition between the two institutes (FAO, 2011).

Private investment in biotechnology research can generate benefits for agricultural sector growth and poverty reduction in developing countries (Spielman, 2007). Private sector companies – Pioneer, Bayer, Syngenta, Pacific, and Charoen Pokphand – started investing in Thai rice breeding programmes (FAO, 2011). Certain limitations, however, have prevented the development of the private sector's role in rice research: in general, rice is a self-pollinating crop (Pingali and Traxler, 2002) and most of the rice varieties in Thailand have been developed by the public sector and are therefore considered public goods. There are some institutional barriers too; for instance, protective policies on access to foreign rice genetic resources, non-existence of biosafety laws, and the prohibition of genetic engineering in open field trials (Napasintuwong, 2018).

The rice sector has attracted additional attention over the last decade. The goals of rice research are to maintain competitiveness in a global market and to enhance Thai farmers' livelihoods. Rice research and extension activities now focus more on adding value to rice. The DoR was officially re-established from the Rice Division in 2006 to respond to the expansion of research and extension activities related to rice production in Thailand. Ciarli and Ràfols' (2019) study indicates that the number of publications on rice research focusing on human consumption aspects has increased across rice-exporting countries, including Thailand. Attempts are being made to generate value-added products through developing innovative downstream products derived from rice, including ingredients for healthcare products, cosmetics, biodegradable materials (Thitinunsomboon et al., 2008). Rice by-products, such as rice straw, rice husk, and rice bran, are also receiving more attention in various industries. This new trend is demonstrated in public investment in rice research in 2008–2017, promoting especially technology development for rice production and rice variety improvement. The budget allocated by the NRCT for this kind of research and for the utilization of rice by-products increased gradually from 0.45 million USD in 2008 to 1.97 million USD in 2017. Crosscutting technologies such as material science, sensors, and information and communication technology (ICT) have become increasingly relevant in the rice sector as a way to enhance the efficiency and the quality of rice production (Figure 3.2).

To summarize, rice research in Thailand has experienced substantial change in terms of organizational structure, governance, and research directions. The rice research focus has shifted from the major technological domains of productivity improvement, the Green Revolution, biotechnology, to currently the integration of upstream, midstream, and downstream segments of the rice value chain. Figure 3.3 visualizes a timeline for the development of the rice research system and the most significant events that have influenced the operational, organizational, strategic, and policy development of rice research in Thailand.

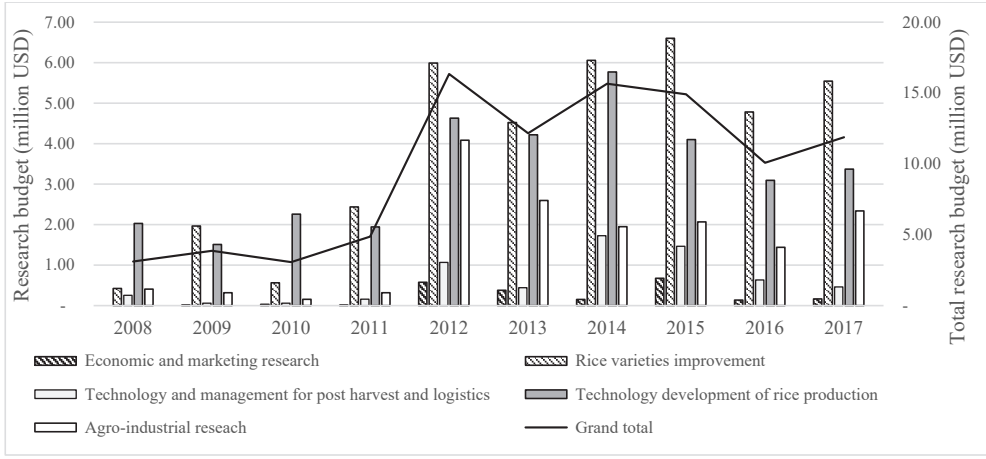

Figure 3.2 Trends in research budget allocated to rice research by the national research council of Thailand in 2008–2017

Source: National Research Council of Thailand, 2017

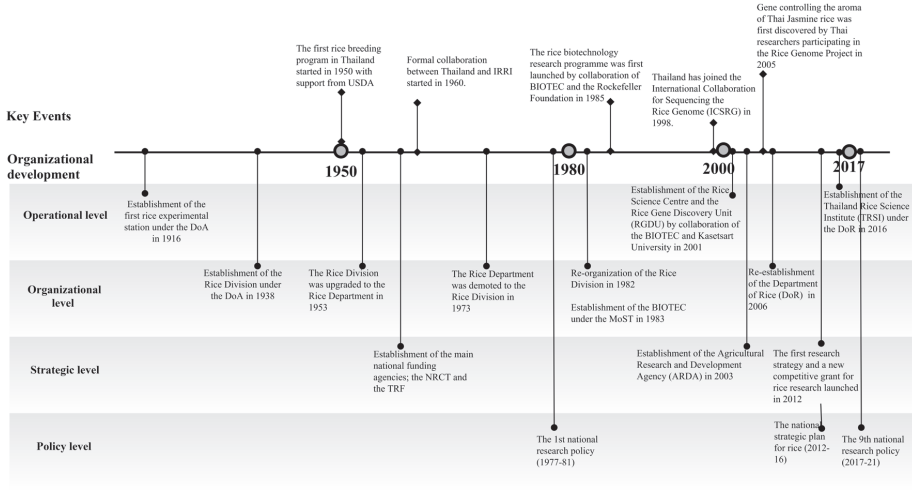

Figure 3.3 Timeline of the development of the rice research system in Thailand and the most influential events

In the next section, a systematic analysis of the development of the rice research system is presented by mapping the functions performed by it in each of the three periods in which the development is studied.

3.4.3 Mapping the functional evolution of the rice research system

This section presents the development in structure, functions, and activities of the rice research system in Thailand. The analysis of functions considers the 1950s as the starting point for the building up of the system. The development phases are considered according to the main changes in each period. The first phase is called the formative stage of the research system (1950s–1990s), the second phase is called the emphasis on science and technology in rice research (1990s–2000s), and the third phase is called the period of strengthening the governance and management of the rice research system (2000–2017). Based on the interviews and data collected for this study, the next sections report on the evolution of the research functions during the three periods.

Phase 1: The formative phase of the Thai rice research system (1950s–1980s)

The rice research system was officially formed after the establishment of the Rice Division and the first rice breeding programme. In this stage, the Green Revolution paradigms had dramatic and widespread impacts on the Thai rice sector. The organizational structures and functions of the Thai rice research system were designed to facilitate the role of rice research in knowledge and technology development for productivity improvement.

Locus of control on the direction of research

The direction for all research in Thailand was broadly guided by the national research policy, which was aligned with the national development plan (Suphannachart, 2015; Isvilanonda and Praneetvatakul, 2003). In the period 1955–1972, the national development plan focused on food security and poverty reduction (Siamwalla, 1975). Therefore, Thai rice research focused on improving rice productivity and income. However, public research organizations and public universities individually interpreted, formulated, and implemented their research agendas. Most of the research performed by the Rice Division was in fact agronomic research focusing on new rice technologies aimed at high yielding varieties or modern varieties, and on the associated agricultural inputs aimed at enhancing rice productivity (Cantrell and

Hettel, 2004; Isvilanonda and Bunyasiri, 2009), whereas public universities conducted research in more diverse disciplines, given that the main function of universities is knowledge production.

Organizational variation and novelty creation

The rice research was conducted mainly by public research organizations under the supervision of the Ministry of Agriculture (MoA) and by public universities under the supervision of the Ministry of Education (FAO, 2011). The commodity-based research division on rice, the Rice Division, was established from an intensive research programme in response to the increased relevance of rice in the Thai economy (Department of Rice, 2011). Reorganizations of the MoA led to the reorganization and decentralization of the Rice Division to solve the location-specific problems in rice production. Local rice research and experimental stations were therefore upgraded to local research centres, and their number increased from two stations in 1950 to 23 stations in 1980. Skilled researchers moved from the central research centres in Bangkok to local research centres spread over the national territory (Pochanukul, 1990).

Resource allocation and dominant funding mode

Most public research organizations in Thailand, including the Rice Division and public universities, were funded through block grants by the national research council: a yearly lump-sum funding was granted on the basis of selected research projects. The remaining funding came from the Thailand Research Fund (TRF). At the organizational level, the allocation of research resources was affected by the reorganization process. In the case of the Rice Division, the budget allocation was also influenced by the reorganization within the MoA and the change in the direction of research. The Rice Division's budget share declined from 50.31% of all crop research expenditure to 44.87% during the period 1959–1967 (Pochanukul, 1990). This change coincided with the redirection of crop research to other crops whose export value was increasing faster than that of rice.

Local diffusion of knowledge in the research system

After the reorganization and decentralization of the Rice Division, the skilled researchers from the central organization mobilized to local research centres. This mobilization strengthened the research capacity and capability of the local centres (Pochanukul, 1990). Knowledge exchange activities occurred via connections between researchers from public universities and public research organizations. However, knowledge exchange took the form of meetings and consulting activities rather than collaborative research. Inter-organizational mobilization of researchers and extramural interactions were still neither occurring nor promoted.

Knowledge diffusion to non-scientific users

After its upgrade in 1953, the Rice Division took responsibility for both research and extension activities related to rice production (Pochanukul, 1990). At the farm level, local research and experiment stations played an important role in providing extension services, mainly through conducting demonstrations and giving advice to farmers located in different agro-economic zones. As in many countries in Asia, the technology and knowledge transfer mechanisms in the Thai rice sector were coupled with support systems for agricultural inputs and credits. Farmers also adopted new practices through learning-by-doing or through information provided by private sector suppliers or extension independent of research (Hazell, 2010; Pingali and Hossain, 1998).

Evaluation procedure

In general, the evaluation procedure adopted in the research-funding process relied primarily on project-based and ex-ante approaches (Isvilanonda and Praneetvatakul, 2003). Researchers' project proposals to work on a particular thematic area, discipline, or ecosystem were selected based on a peer-review procedure at the NRCT and the TRF. The Rice Division adopted an internal peer-review process to select research projects sent by internal research units and by regional research centres before submitting these to the NRCT, whereas the research proposals elaborated by public universities and other public research organizations were submitted directly to the

NRCT and the TRF. The monitoring and evaluation (M&E) system for the funded research projects required only progress reports and final reports, which were peer reviewed (Sungkhaworn, 2012). Research outputs, for instance technologies, varieties, and publications, were also used at the organizational level for internal evaluations of research performance.

International orientation

At the formative stage, the Thai rice research system experienced a scarcity of knowledge and human resources that was later remedied by technical and financial assistance from international agencies, including USDA, USOM, IRRI, and the Rockefeller Foundation (Isarangkura, 1986; FAO, 2011; Napasintuwong, 2018). These agencies had an important role in producing scientific knowledge and forming human resources in rice research. A notable turning point was the collaboration with IRRI in 1960 in the rice breeding programme.

The structure and key processes that directly influenced the development, diffusion, and use of new knowledge in the rice research system started in this formative period (Figure 3.4). The main emphasis in the system was on public research and support from international agencies, but the role of private research and the participation of farmers or users in the research system were still absent in this period.

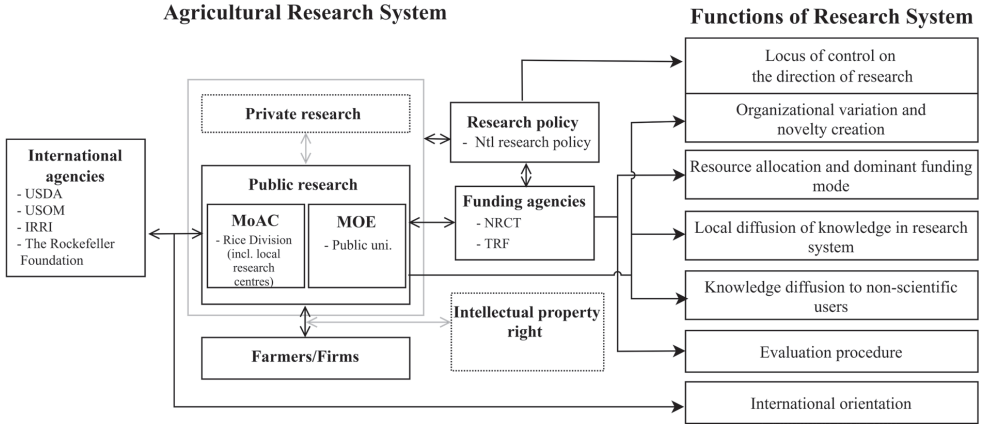

Figure 3.4 Structure, relations, and functionality of the rice research system in the formative phase (1950s–1980s)

Phase 2: The emphasis on biotechnology and molecular biology in rice research (1990s–2000s)

Scientific and technological advances in the fields of biotechnology and molecular biology were integrated in rice research starting in Phase 2 and were rapidly applied by both the public and the private sector. This section describes the functional development of Thai rice research during the period 1990s–2000s.

Locus of control on the direction of research

The development and applications of biotechnology in rice research were emphasized in the ninth national development plan (2002–2005) (Suphannachart, 2015) and the first biotechnology development plan officially formulated in 2003 (The United Nations, 2015). However, the rapid rise of biotechnology in rice research met divergent research agendas at the organizational level. The Rice Division still focused on conventional breeding and agronomy research under the Green Revolution paradigm, whereas BIOTEC focused on rice biotechnology research. Despite the fact that the Rice Division and BIOTEC both aimed for coherent research agendas, they struggled with the different scientific cultures and institutional settings of their organizations (FAO, 2011), and this prevented the achievement of a joint plan for the direction of research.

Organizational variation and novelty creation

Acknowledgement of the potential of biotechnology in rice research led to new research units for rice biotechnology being established in public research organizations, public universities, and private companies. The Rice Science Centre and the Rice Gene Discovery Unit (RGDU) were established in 2001, with collaboration between BIOTEC and Kasetsart University, aiming to develop and utilize biotechnology as a tool for improving Thai rice varieties (Damrongchai, 2002; FAO, 2011). Rice biotechnology research laboratories were established under the Rice Division. Private companies also started developing research units to improve rice genetically (FAO, 2011). However, technical property restrictions imposed by Thailand's 1999 Plant Variety Act and the seed law enacted in 1975 impeded further development of the private sector, especially international companies. Only a Thai

company, Charoen Pokphand, engaged in rice research and successfully registered the first hybrid rice in 2011.

Resource allocation and dominant funding mode

The emergence of a biotechnology paradigm in rice research led to different research-funding channels and mechanisms. The main funding source for rice research was still the NRCT, which allocated block funding for rice research activities to the public sector. BIOTEC and the NSTDA under MoST provided funding for research activities related to rice biotechnology through a competitive mechanism. The rice biotechnology programme was first launched in Thailand by BIOTEC in collaboration with the Rockefeller Foundation in 1985 to support researchers from universities and public research organizations working on the development of molecular markers for rice breeding, hybridization technology, and so forth (Damrongchai, 2002). Competitive funding contributed greatly to enhancing capacity and collaboration for rice biotechnology research among public research organizations and public universities.

Local diffusion of knowledge in research systems

At the beginning of this phase, most of the rice research performed at the Rice Division revolved around conventional plant breeding and yield-improving technologies. The modern biotechnology in rice breeding was limited to BIOTEC and the universities, which had a leading role in this sector (Napasinthuwong, 2018). Despite the different focus, several programmes promoted by BIOTEC – and providing opportunities for capacity building by means of research collaborations – supported the Rice Division and other research agencies to enable them to start working together on research areas such as the development of molecular markers for rice breeding, the hybridization of rice, and other applications of biotechnology in rice research. However, when interviewed, researchers pointed out that knowledge exchange deriving from the public research collaborations was quite limited because of the different administrative structures, research focuses, and cultures among the actors involved.

To mention one case, Charoen Pokphand, the only private company conducing rice research, had limited collaborations with public research institutes.

Diffusion of knowledge to non-scientific users

Knowledge and technology were transferred to farmers mainly via seed multiplication and seed production programmes. The Rice Division adopted a participatory approach to the breeding programme for rain-fed lowland rice. The farmers could work with the researchers in the variety selection and the evaluation process (FAO2011). BIOTEC launched the Seed Production Training Programme to distribute and promote seed production of submergence tolerant rice to farmers that participated to the programme and were based in the areas most affected by floods (Toojinda and Lanceras-Siangliw, 2013). The importance of adopting an IP system started to be acknowledged in Thailand in this phase. The 1999 Plant Variety Protection Act provided benefits to breeders, farmers, and local communities (Lertdhamtewe, 2015).

Evaluation procedure

As in the previous period, research proposals were selected based on ex-ante peer-review evaluation. Monitoring and ex-post evaluation of research projects were occasionally conducted. In 1992 and 2000, the NRCT conducted an M&E of the research-funding process with the aim of determining how effective and efficient its research budget allocations were, as well as identifying the barriers in research operations and utilizations and the recommendations needed to improve the process (Suphannachart, 2015). Nevertheless, no evaluation programme was specifically issued for rice research.

International orientation

Thai rice research started becoming more engaged with the global scientific community. Apart from being a member of IRRI, Thailand joined many international consortia related to rice research. For example, when BIOTEC joined the International Collaboration for Sequencing the Rice Genome (ICSRG), the Rice Genome Project was launched, which allowed the discovery of the aroma gene in Thai rice. This resulted in Thailand opening up to the international scientific community, incorporating state-of-

the-art technology, and finally improving Thailand's competitive advantage in the international rice research community (Damrongchai, 2020). International collaborations represented the way also for private research to advance in rice research: Charoen Pokphand, leading research on hybrid rice, became a member of IRRI consortia too. Information sharing, capacity building, and resource support were the main ways in which Thai rice research, both public and private, benefitted from international collaborations.

In summary, during this second phase, the direction of rice research in Thailand moved towards the biotechnology paradigm, thereby influencing the research system itself in terms of structure and functionality, as indicated in Figure 3.5. New researchers such as science and technology research organizations were now involved in the rice research system and later became key contributors to the development of specific functions of the system, such as locus of control on the direction of research, organizational variation and novelty, resource allocation and dominant funding mode, knowledge diffusion within the research system and to non-scientific users, and international orientation. In addition, new institutional arrangements such as IP rights were introduced to support the system's knowledge diffusion function.

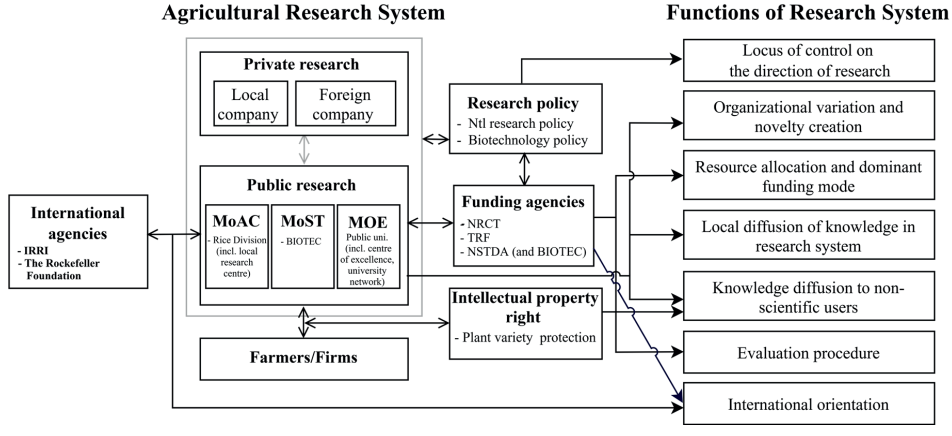

Figure 3.5 Structure, relations, and functionality of the rice research system, 1980s–2000s

Phase 3: Strengthening the governance and management of the Thai rice research system (2000–2017)

Since 2003, the national research system in Thailand has undergone a reformation process aimed at strengthening its governance and management. The reformation consisted of several main initiatives: a network of funding agencies and public research organizations was formed, called the Thailand Research Organizations Network (TRON); a new national research management system was established, including an online system called the National Research Management System (NRMS); finally, new thematic competitive funding schemes were implemented in order to support the development of rice research nationally. In addition to this reformation, new organizational settings in public research organizations have influenced the structure and management of rice research.

Locus of control on the direction of research

An outcome of the previous phases, the lack of harmonization of the research agendas of the different organizations involved in previous decades had long been criticized for its clear influence on the direction taken on research on both rice and other crops. A collaborative research agenda was, therefore, developed after TRON was formed in 2003. The first national rice research strategy officially published with the cooperation of the NRCT, the NSTDA, ARDA, and the DoR focused on enhancing the competitiveness of Thai rice in the global market, covering the entire rice value chain. This strategy was implemented to stimulate the integration of rice research in different sectors, such as the pharmaceutical sector, the energy sector, and the environment, with the provision of a new competitive grant.

Organizational variation and novelty creation

After the establishment of TRON, ARDA was specifically assigned the task of managing a new competitive funding scheme for important commodities including rice: the Targeted Research Grant. The expansion of research areas, which required a stock of knowledge on rice under different disciplines, led to the new establishment of organizations, for instance the re-establishment of the DoR from the Rice Division to

expand rice research capacity (Department of Rice, 2011) and of a new institute, the Thailand Rice Science Institute, under the DoR. New research units performing crosscutting research, for instance the National Metal and Materials Technology Centre and the National Electronics and Computer Technology Centre, increased their roles in working with the DoR on rice research. In addition, research networks were built among public universities to enhance the integration of rice research, for instance the Research University Network for rice and the Rice Innovation Centre of Excellence under Kasetsart University. Notwithstanding the attempts to harmonize the structure of the research system, the activities of these networks were limited by the absence of continuous financial support.

Resource allocation and dominant funding mode

The Targeted Research Grant was launched and managed by ARDA with the aim of funding cooperative research among different disciplines. The implementation of this grant scheme in rice research is reported to have encouraged interactions between research organizations, universities, and stakeholders such as farmers and rice sector industries. However, according to the researchers interviewed, the major funding provided by the NRCT was criticized for unclear direction and redundancy. The decisions on resource allocation were always based on past allocating patterns and vague agendas.

Local diffusion of knowledge in the research system

The Targeted Research Grant led to collaboration among researchers from different research areas within and between research organizations. Approximately 25% of the research projects funded by the grant in 2012–2017 were collaborations between different research organizations. According to the interviewees, researchers working at the DoR perceived that collaborative research with universities and other research organizations represented a valuable way to develop knowledge and research capacity, given that the DoR had always experienced a lack of human resources, research capacity, and technology. Despite the formation of a collaborative research agenda, organizational factors, namely different research agendas, administrative

structures, and research cultures, were still characterized in this phase as factors limiting the potential increase of collaborative research among the public research organizations. In addition, ownership of research became a major issue concerning collaborations among public research organizations and universities.

Diffusion of knowledge to non-scientific users

Interaction between public research organizations and non-scientific users such as farmers and industry increased through different approaches. The DoR developed strategic actions for technology development and transfer, including building networks and platforms with rice farmers for technology transfer, promoting ICT for field data management and transfer of knowledge, and conducting research on social and economic rice issues (Napasintuwong, 2019; Sangbuapuan & Guha, 2015). The DoR also contributed to transferring knowledge together with non-government organizations and the private sector. The private sector paid more attention to investment in R&D through collaborative research with the DoR and universities (for example, the DoR supported the manufacture of Kellogg's products through its rice breeding project). However, private sector investment in R&D activities in rice research remained low. Researchers in the DoR and universities emphasized that, in order to foster the linkages between rice research and the private sector, policies and guidelines for the implementation of IP rights needed to be improved.

Evaluation procedure

As a platform to manage and monitor research budget allocations, the NRMS was developed to systematically collect data from research projects, including research budget, time durations, expected output and outcomes. In addition, the NRCT attempted to establish a roadmap for systematic monitoring and impact evaluation of research programmes. National research evaluation exercises were carried out in 2013 and 2015, including the ex-post impact evaluation of rice research for example (NRCT, n.d.). However, an explicit protocol for a national research evaluation procedure seemed to be still in the development stage in this phase. Research funding organizations only intermittently conducted M&E on their research.

International orientation

The Thai rice research community developed a capability equal to international standards, especially in rice biotechnology research. The Thai rice researchers were able to access various sources of funds and increasingly worked with many foreign universities and research institutes, as evidenced by the increased number of publications on rice from 134 in 1998–2007 to 506 during 2008–2017 (source: Scopus, 2017). Public research organizations and public universities continued their long-standing collaboration with international agencies such as IRRI and the Rockefeller Foundation. Furthermore, Thailand was involved in a South–South cooperation aimed at supporting rice-breeding research among the Mekong region countries. The Molecular Rice Breeding Programme for the Mekong Region was set up in a collaboration between BIOTEC and Kasetsart University in order to provide training programmes, sharing genomic information and research facilities among the Mekong region countries (Toojinda and Lanceras-Siangliw, 2013).

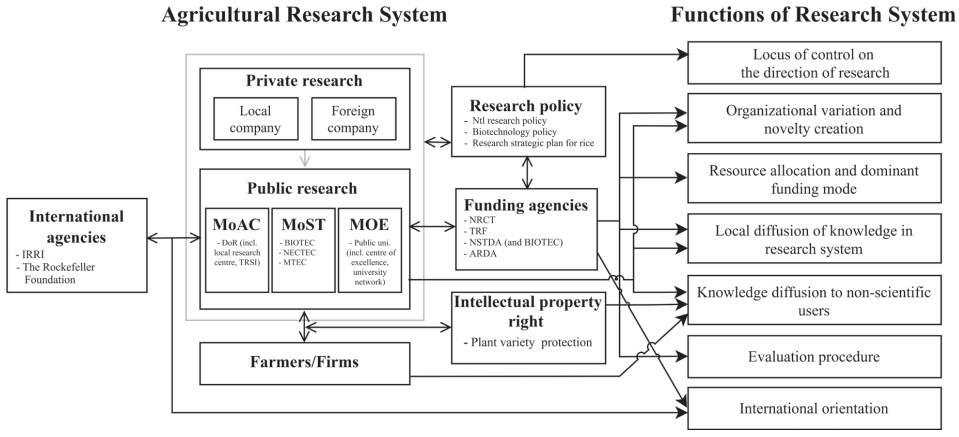

Figure 3.6 Structure, relations, and functionality of rice research system, 2000–2017

In summary, with the aim of improving research management and governance, during this phase the Thai rice research system gradually developed in terms of organizational structure, governance, and management. Functions such as locus of control on the direction of research, resource allocation and dominant funding mode,

and evaluation procedure obviously improved compared to the previous phases (Figure 3.6).

3.5 Analysis and Discussion

Using the functional approach, this study aimed to illustrate the evolution of the ARS in the rice sector in Thailand from 1950 to 2017. The findings show that, in line with other work on ARS development (see Byerlee, 1998; Roseboom & Rutten, 1998; Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004; Bin et al., 2013; Gijsbers and Tulder, 2011), the rice research system in Thailand has developed over time in terms of its organizational structure, management, and governance in order to respond to challenges within and outside the research system.

The existing literature on ARS development focuses mostly on, and explains, structural and financing changes (see Byerlee, 1998; Roseboom & Rutten, 1998; Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004). However, prior studies do not explicitly explain how the changes in structure and financial management relate to ARS development in terms of focus and activities. The application of the functional approach to the analysis enabled us to better capture the evolution of structural characteristics in relation to the dynamics of the key processes or *research system functions* (Jonkers, 2011). This allows for deepening insights regarding how the co-evolution process relates to the overall functional development and the co-evolution of technological paradigms and institutional arrangements in the rice research system (Figure 3.7).

In the next section, a reflection on the main findings is given with regard to: 1) the interlinkages in the functional development of the rice research system and 2) the co-evolution of technology and institutional arrangements in the rice research system

3.5.1 The interlinked functional development of the rice research system

The functions of the research system developed differently in different periods. Table 3.2 gives an overview of this evolution. The main technological paradigms – the Green

Revolution, biotechnology, and later the agri-food value chain – influenced the direction of rice research. In accordance with developments in other developing countries (Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004), the organizational structure of the Thai rice research system was initially built along with the adoption of the Green Revolution paradigm, and, later, institutional developments occurred to respond to rapid changes in technological and economic paradigms. The developments in the organizational structure of the Thai rice research sector thus were directly connected to the research system's functions *organizational variation and novelty creation* and *locus of control on the direction of research* through the participation of a wide range of actors in rice research and the establishment of new organizational forms (Figure 3.7).

The function *organizational variation and novelty creation* also reinforces the development of other functions. This is exemplified in the case of the reorganization of the Rice Division and the establishment of the DoR, which influenced the allocation of research resources within organizations and knowledge development and diffusion. This finding accords with Jonkers' (2011) study explaining that the availability of factors such as research infrastructure, the presence of highly skilled manpower, and a suitable organizational structure contributes to the creation and diffusion of knowledge. In addition, the participation of a variety of research organizations in the Thai rice research system influences the *diffusion of knowledge within the research system*, including collaboration among researchers from different research areas within and between research organizations. The diversity of research organizations participating in a research system can reinforce that system's quantity and quality, especially in terms of financial and human resources (Byerlee, 1998). Hence, there seems to be a catalytic effect: a solid basis of organizations enhances the ability to adapt the research system's structure and focus to cope with new demands. Furthermore, the diffusion of knowledge also strengthened the function *international cooperation* in terms of increased research collaborations and cooperation with international agencies. However, this also raised new problems. The establishment of numerous new research organizations resulted in research organizations having overlapping mandates, which is a frequently noted problem (Roseboom & Rutten,

1998). Experience from the Indian ARS also suggests that a growing number of organizations participating in agricultural research led to duplicating and overlapping research areas (Mruthyunjaya & Ranjitha, 1998). Such a growing complexity of agricultural research creates the need for research organizations to develop partnerships and networks at both national and international level (Byerlee, 1998).

Another noticeable finding is that the development of the rice research system's functions *resource allocation and main funding mode* and *evaluation procedure* has relatively lagged behind. Although competitive funding schemes have been applied, most rice research in Thailand has been funded through block funding with low competition. M&E activities are neither efficiently operated nor linked to one another. According to the research system typology proposed by the OECD (2003), the funding modes and evaluation in a research system can be characterized as centralized with a strong top-down management approach. This possibly implies a mismatch between the demand–supply of the research system and the way in which these two functions are organized. This suggests that decentralization, including the creation of autonomous research organizations and the devolution of authority for priority setting and resource allocation (Rajalahti et al., 2005), may be necessary to improve administrative management and to make agricultural research more impact oriented, like in many countries (see Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004). The structure of the rice research system in Thailand reflects rather an incremental strengthening than a fundamental re-examination of the governance of public research. Literature exists on reforms in ARSs (see Byerlee, 1998; Roseboom & Rutten, 1998; Mruthyunjaya & Ranjitha, 1998; Huang et al., 2004), but this study adds that the different structural elements within ARSs, and the functions that they support, need to be synchronized to make reforms effective. This points to the importance of being aware of, and monitoring, the co-evolution between research system structures and functions, further discussed in the next section.

3.5.2 *The co-evolution of technological paradigms and institutional arrangements in the rice research system*

The chronological development of rice research in Thailand reflected a shift in mainly two technological paradigms focusing on rice production (namely, the Green Revolution and the biotechnology paradigm) from a field and farming system focus towards covering the whole rice sector value chain. The paradigm shift led to new institutional arrangements, which strengthened the existing institutional capacity by improving management of the rice research system, such as participation by a wider range of research organizations, new funding mechanisms, consolidation of the network of research organizations, and an increased role for the private sector. The increased prominence of biotechnologies and interest in the agri-food value chain required new competencies that were not always available within one organization (Rajalahti et al., 2005). The science and technology research organizations started participating in rice research, resulting in an increase in new funding sources and in an advanced capability of biotechnology and crosscutting research on rice. This has also been observed in other studies on the development of ARS in developing countries where agricultural biotechnology has become a key factor in improving food security and agricultural productivity and in enhancing competitiveness on international markets (see Laxmi et al., 2007; Huang et al., 2004; Spielman, 2007).

Shifting to the agri-food value chain paradigm allowed a wider range of actors to provide knowledge and to increase the use of knowledge. Previously, the Green Revolution was predominantly led by public research. Public research was mostly oriented towards the agricultural production sector rather than towards the food processing sector (Fuglie and Toole, 2014). The private sector's growing role is recognized as a major source of food and agricultural innovation, encouraging agricultural research to embrace the entire value chain of the agri-food sector (Reardon et al., 2019). New institutional arrangements including trade and investment regulations, IP and other property rights, and food quality and safety standards have been established to facilitate the inclusion of actors in the research (Gijsbers and Tulder, 2011; Fuglie and Toole, 2014).

In developing countries however, the tendency of institutional arrangements in agricultural research is often to seek for alternatives to public research rather than to focus on enhancing the integration of stakeholders into the existing system (Hall et al., 2000). The experience of the rice research system in Thailand is similar to that in other developing countries where the ARS structure is dominantly formed and developed by a closed group of public research organizations. Interaction aimed at developing and diffusing knowledge with the private sector remains low (see Laxmi et al., 2007; Huang et al., 2004). This provides an important lesson, whereby ARS development should concentrate on institutional arrangements that facilitate the research system's functions in the widest sense (reflecting ideas by Fuglie, 2016) and its connection with the broader innovation system (Hall et al., 2000; Hall et al., 2006)

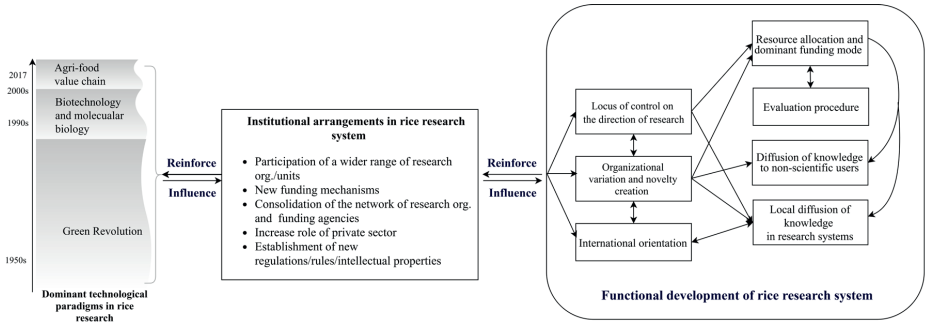

Figure 3.7 Functional development and co-evolution of technological paradigms and institutional arrangements in the rice research system

3.6 Limitation and future research

This paper empirically applied Jonkers' (2011) functionalist approach to analyse an ARS's evolution. The advantage of using the functionalist approach to assess the evolution of a research system is that the seven functions represent the crucial process of development of a research system and allow for an assessment of the relation between functional development and the connection with structural characteristics. The application of the functionalist approach is of particular interest to track and monitor the progress of research system reforms. However, given the case approach,

our analysis does not allow for assessing performance of the rice research system in Thailand and for benchmarking with other countries, because of data limitations and the absence of concrete quantitative indicators for each function. This could be an avenue for further development of the functional approach, for example in connection with efforts by the Agricultural Science and Technology Indicators Initiative (ASTI – see https://www.asti.cgiar.org/).

3.7 Conclusion and policy recommendations

Taking the case of the rice research system in Thailand, this study aimed to examine the evolution of an ARS in a developing country setting. The evolution of the Thai rice research system is analysed in light of its structure and functions – locus of control on the direction of research, organizational variation and novelty creation, resource allocation and dominant funding mode, local diffusion of knowledge in the research system, knowledge diffusion to non-scientific users, evaluation procedure, and international orientation – which have developed through different periods of time. The chronological development of Thai rice research reflected a shift in technological paradigms focusing on rice production, namely, the Green Revolution, biotechnology, the agri-food value chain. These paradigm shifts led to new institutional arrangements in order to strengthened the existing institutional capacity. The study has also demonstrated that institutional arrangements reinforce the research system functions.

The lessons and experience from the development of Thailand's rice research system resulting from the dynamics of evolutionary processes may have implications for other developing countries. Some pertinent policy implications can be derived from the findings. In order to respond to shifts in the technological rice research paradigms, the new institutional arrangements focusing on structural development of the research system have continuously developed and led to functional development and, conversely, the functional development has reinforced the institutional arrangements. According to the case study, the functional development seems not to be inclusive. This finding suggests that, apart from structural development of the research system, the institutional arrangements should focus on improving the efficiency and the

effectiveness of public research. First, the rice research system has a strong centralized top-down management that results in the slow development of the functions relating to characteristics of research planning and M&E. Decentralization of public sector decision making and resource allocation can be key factors in making rice research more efficient and responsive to research demands. Secondly, shifts in the dominant technological paradigm allow new research areas and new actors to engage in rice research. There have been collaborations both among the public research organizations and universities and between public research and the private sector, including farmers. The institutional arrangements of the existing public agricultural research should be complemented with the implementation of other policies related to the agri-food system rather than only agriculture; in particular, those related to facilitating private sector participation in research and technology transfer, IP rights, legislation, and market regulations (Roseboom & Rutten, 1998).

Table 3.1 The seven functions of the rice research system in Thailand and their evolution over time

Functions	The formative phase (1950s–1980s)	The second phase (1980s–2000s)	The third phase (2000s to 2017)
Locus of control on the direction of research	• Policy levels influence the direction of research • Focus on enhancing productivity through farm technologies and variety improvement	• Policy levels influence the direction of research • Focus on enhancing productivity through farm technologies and variety improvement	• Organizational levels participate in deliberation of direction of research • Focus on enhancing productivity through farm technologies, variety improvement, and upstream activities (processing, trade, storage)
Organizational variation and novelty creation	• Responsibility of the MoA and public universities • Internal reorganization in the MoA	• Responsibility of the MoA and public universities, only partly shared with MoST • New operational units arrangement in both public and private research	• Responsibility of the MoA, MoST, and public universities • Limited roles of private sector in rice research • Network arrangements within and between organizations
Resource allocation and dominant funding mode	• Mainly publicly funded by the national research council • Yearly lump-sum funding through project-based scheme	• Mainly publicly funded by the national research council • Yearly lump-sum funding through project-based scheme • New competitive funding scheme in a specific thematic area: rice biotechnology	• Mainly publicly funded by the national research council • Yearly lump-sum funding through project-based scheme • New competitive funding scheme for demand-oriented research

Table 3.1 (continue)

Functions	The formative phase (1950s–1980s)	The second phase (1980s–2000s)	The third phase (2000s to 2017)
Local diffusion of knowledge in research system	• Mobility within organizations; no inter-organizational mobility • Cooperative work within organizations • Information exchange between organizations via meetings, consultations, and publications	• Mobility within organizations; no inter-organizational mobility • Low cooperative work between organizations • Information exchange between organizations via training, meetings, consultations, and publications	• Mobility within organizations; no inter-organizational mobility • Relatively increased cooperative work between organizations • Information exchange between organizations via training, meetings, consultations, publications, and collaborative research
Knowledge diffusion to non-scientific users	• Knowledge/technology transferred through extension (linear model) • Support by private sector and international organizations	• Knowledge/technology transferred through participatory extension and network • Increased support from local government, universities, and farmers' groups	• Knowledge/technology increasingly transferred to enterprise/industrial sector • Increased participation by local government, universities, industry, and farmers' groups
Evaluation procedure	• Ex-ante evaluation of research proposal; reliance on peer review • Monitoring and evaluation procedure intermittently operated; no specific procedure for rice research	• Ex-ante evaluation of research proposal; reliance on peer review • Monitoring and evaluation procedure intermittently operated; no specific procedure for rice research	• Ex-ante evaluation of research proposal; reliance on peer review • Monitoring and evaluation procedure intermittently operated; procedure for rice research in progress

Table 3.2 (continue)

Functions	The formative phase (1950s–1980s)	The second phase (1980s–2000s)	The third phase (2000s to 2017)
International orientation	• Dependency; bringing in knowledge, technologies, and skills of foreign experts to enhance capacity • Collaborative research with international research agencies	• Increased research competitiveness towards international scientific community • Increased collaboration research with various international research agencies	• More internationally oriented through relatively increased collaborative research and cooperation with diverse international research agencies

Note: MoA = Ministry of Agriculture; MoST = Ministry of Science, Technology, and Innovation

Chapter 4

Understanding the heterogeneity of agricultural researchers in engaging with impact orientation: Individual perspectives of rice researchers in Thailand

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Abstract

This study aims to explore how individual and organisational characteristics determine different forms of engagement of researchers in impact-oriented activities using the case study of agricultural researchers conducting research on rice in Thailand. Impact orientation of agricultural research is co-determined by factors at different levels. The institutional context at the organisational level influences the way individuals define their professional identities, roles and routines and therefore the way individuals orient their work towards producing an impact. The evidence from the case study shows the identification of three different groups of researchers based on the activities related to the impact orientation of their research, namely involving stakeholders in research, transferring knowledge and engaging in policy process. The result of the study shows that the factors, including work experience, types of organisation, attitudes towards impact-oriented activities and perceptions on supportive conditions in organisations, were identified as determinants of the different degree of engagement in impact orientation practices of researchers. This study suggests that organisational supportive conditions and incentives should pay more attention to facilitating and strengthening different kinds of interaction with stakeholders rather than only the volume of research outputs.

Keywords: researchers; impact-oriented activities, impact orientation, individual factor, agricultural research

4.1 Introduction

Public research increasingly aims to contribute to solving societal challenges as a result of globalisation, urbanisation and environmental problems (Gijsbers and Tulder, 2011), especially in outcome-oriented areas such as agriculture. This aim is reflected in the concept of impact orientation, which for the agricultural sector mostly refers to the way in which research contributes to societal change. Examples include enhancing strong linkages with farmers and stakeholders, the adoption of demand-driven research methods and the definition of strategies for research planning for human resource development and for research programme management that supports the pursuit of development goals (Springer-Heinze et al., 2003).

Impact orientation of agricultural research is co-determined by factors at different levels, those being the organisational level and the personal or individual level (Amoa-Awua et al., 2003). At the organisational level, an institutional context can be distinguished in both formal organisations, such as research organisations, and informal structures, such as peer networks or communities in which researchers operate (Klerkx et al., 2017), that influences the way individuals define their professional identities, roles and routines and therefore the way they orient their work towards producing an impact (Hall et al., 2001; Hartwich and Springer-Heinze, 2004; Klerkx et al., 2017). This institutional context guides processes such as agenda-setting, fund allocation and incentive schemes, that from the organisational level influence research and knowledge transfer processes performed by individual researchers (Klerkx and Leeuwis, 2008; Klerkx et al., 2017).

At the same time, the impact orientation of organisations is influenced by the way individuals belonging to the same organisations embrace the norms, routines and actions embedded in the institutional context which characterises those organisations (Bercovitz and Feldman, 2008). Thus, there is a mutually reflexive relationship between factors pertaining to the individual level and to the organisational level when it comes to defining the impact orientation of research. In fact, both organisational and individual factors determine how researchers shape their activities to respond to

scientific and societal objectives (see Perkmann et al., 2013; Haeussler and Colyvas; 2011; Dabic et al., 2015; Azagra-Caro and Llopis, 2018).

Among these individual factors, literature has indicated that demographic characteristics, previous experiences and personality traits (such as attitudes and perceptions) of individual researchers influence the activities they perform in order to produce an impact and to contribute to the impact orientation of their organisation (Lam, 2011; Perkmann et al., 2013; Haeussler and Colyvas; 2011; Azagra-Caro and Llopis, 2018). In particular, the prior studies found that when researchers who perceive their organisational conditions as offering positive support for their research activities, they likely demonstrate the positive qualities of the research activities they perform (Olmos-Peñuela, Benneworth and Castro-Martínez, 2015). Moreover, individual researchers differ in their understanding and expectation on how both their own research activities and the organisation conditions in which they operate support their impact orientation (Amoa-Awua et al., 2003). Thus, analysing how individual and organisational characteristics determine different forms of engagement of researchers in impact-oriented activities can help researchers and their organisations design processes that result in a successful impact orientation.

This study addresses the issue in the context of agricultural researchers conducting research on rice in Thailand. In recent decades, rice research in Thailand has undergone a transformation process in terms of both technical and institutional aspects, which is supportive of understanding how individual and organisational characteristics determine different forms of engagement of researchers in impact-oriented activities. In fact, the Thai research system has experienced several changes in terms of research policies. It underwent a decentralisation process while markets became more open to international influences, all in response to the challenges the national agricultural sector has been facing. Researchers and researcher organisations are therefore asked to revisit their roles in impact-generating process. The study is structured as follows. Section 2 presents the background and conceptual framework of this study. Section 3 presents problem definition and empirical strategy. Data, variables and method are explained in Section 4. Section 5 presents the results. Finally,

discussion, conclusions and implications are presented in Sections 6 and 7, respectively.

4.2 Background and conceptual framework

4.2.1 Activities researchers perform for impact orientation

Researchers are conventionally seen as those who produce and transfer knowledge. Knowledge production traditionally refers to the production of (new) knowledge by means of conducting research (Jacobsson and Perez Vico, 2010). This entails researchers conducting several activities, including systematically collecting, analysing, interpreting and reporting data. Knowledge transfer includes knowledge exchange, which implies the creation of new knowledge through the exchange of information on a multi-level basis: individual, intra-organisational or inter-organisational level (Baskerville and Dulipovici 2006; Wilkesmann and Wilkesmann 2011). For the agricultural sector, public research organisations have been seen as traditionally providing knowledge and technology either directly to users (i.e. farmers, processing companies, agricultural input suppliers) through agricultural extension services or indirectly through publications and media channels (Bozeman, Rimes and Youtie, 2015).

Due to the complexity of social, economic and environmental challenges, the understanding of how research interacts with society has evolved from this rather traditional linear model of knowledge production and transfer to a more interactive research and innovation process (Röling, 2009). The impact orientation of agricultural research reflects the need for researchers to engage with stakeholders and research users (e.g. farmers, policymakers, the business sector) (Klerkx and Leeuwis, 2009; Mcnie, Parris and Sarewitz, 2016). Apart from collecting, analysing, interpreting and reporting data, researchers do engage in a wider range of activities aiming, for instance, at jointly facilitating the learning process and the generation of knowledge with other actors (Wittmayer and Schäpke, 2014; Nagasaka, Böcher and Krott, 2016; Schut et al., 2011). In order to facilitate the interaction between research and these actors, new research approaches have emerged, such as participatory research, action

research and research commercialisation (Neef and Neubert, 2010; Wittmayer and Schäpke, 2014; Halilem, Amara and Landry, 2011). Although these approaches are different in their objectives, they suggest the relevance of the interaction between research and society. The participation of stakeholders in research can take various forms, and the degree of their participation can be from low to high. Stakeholders can take a passive role in information sharing; for instance, researchers might consult them to build their research design based on expressed needs. However, stakeholder expertise and knowledge can be also more formally recognised in order to be involved in assessing the research process and results. In any case, when joining forces, researchers and stakeholders engage in mutual learning (Neef and Neubert, 2011; Wittmayer and Schäpke, 2014). Furthermore, as a result of the debate on the mobilisation of research findings to influence policymaking, researchers have been pressured to reconsider their role in contributing to the policymaking process as well (Schut et al., 2011), for instance by providing their insights (Schut et al., 2011) or attending discussions on strategies for policy (Nagasaka, Böcher and Krott, 2016).

Figure 4.1 offers a conceptualisation and visualisation of the roles and the activities researchers respectively play and perform in the context of this study to respond to impact orientation by means of engaging with society. As research has shifted away from viewing society as simply a knowledge recipient towards envisioning more complex and interactive forms of knowledge creation and dissemination for policy and practice (right top side of the figure), feedback comes from society that is the starting point for the creation of new knowledge (bottom of the figure).

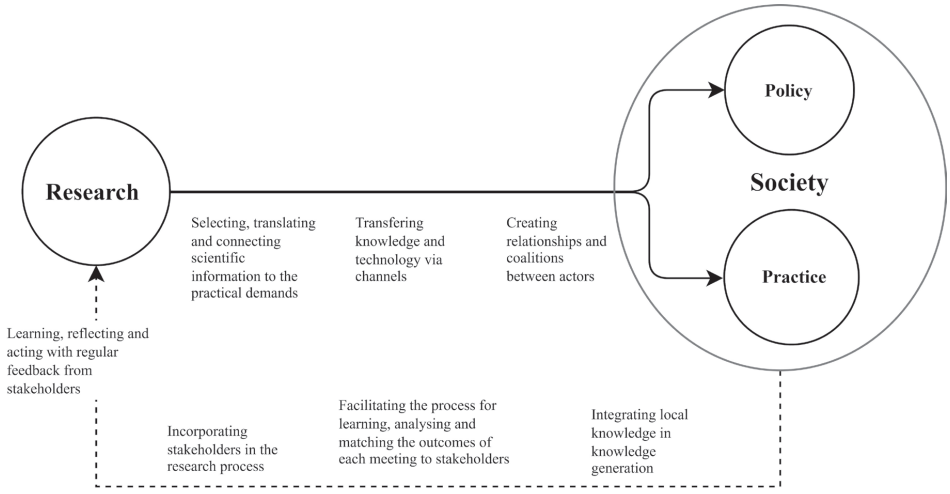

Figure 4.1 Roles of researchers conducting to link research to society.
Source: adapted from Neef and Neubert (2011); Wittmayer and Schäpke (2014); Schut et al. (2011); Nagasaka, Böcher and Krott (2016)

4.2.2 The individual and organisational determinants of research impact orientation

The literature indicates that factors influencing researchers to perform activities that produce an impact (e.g. benefit to society) pertain both to the individuals and their organisations (Bercovitz and Feldman, 2008; Olmos-Peñuela, Benneworth and Castro-Martínez, 2015; Rosenlund, Notinia and Bravo, 2015). In fact, the scientific and societal impact emerging from the activities of individual researchers is likely influenced by a set of individual characteristics, institutional and organisational settings in which the research is conducted and their interactions (D'este et al., 2015).

Different types of individual researchers can be identified in relation to the role they play in the impact orientation of their research. Dabic et al. (2015) found, for instance, that individual characteristics of the researchers can influence the impact-oriented activities they might perform. In particular, individual factors for instance demographic characteristics (e.g. age and gender, academic qualifications) (Landry, Amara and Rherrad, 2006; Haeussler and Colyvas, 2011), experiences, attitudes and perceptions are important determinants for researchers to perform impact-oriented activities (Olmos-Peñuela, Benneworth and Castro-Martínez, 2015). The researchers'

experience in carrying out research is found to contribute to how they shape their research activities to respond to scientific and societal objectives (D'este et al., 2015). Following Rosenlund, Notini and Bravo (2017), the evidence shows that experience in research affects how researchers reflect on the societal relevance of their research and of their dissemination activities. Experience in specific activities helps researchers to deal with uncertainties and encourages them to carry out the same activities again (Olmos-Peñuela, Benneworth and Castro-Martínez, 2015). Evidence is also found that individuals' attitude towards their profession explains the engagement of researchers in a broad range of knowledge transfer activities (D'Este et al., 2018). Previous studies also highlighted that a researcher's attitude is positively related to collaborative and participatory research (Neef and Neubert, 2011; Rosenlund et al., 2017).

Organisations where researchers work with, for instance, universities or research organisations, can also influence individual researchers' decision to perform their activities due to the different organisational structures, cultures and policies of the organisations. Activities related to technology transfer and research commercialisation are found to be conducted differently when researchers are employed at a university compared to public research organisations (Haeussler and Colyvas, 2011). The organisational conditions include the existence of a working environment and infrastructure regarding physical and human resources that are supportive of oriented research activities (D'este et al., 2015; Landry, Amara and Rherrad, 2006; Haeussler and Colyvas, 2011). The organisational conditions are found to influence researchers' decision to perform more impact-oriented research activities, and this varies across specialisations and disciplines (Olmos-Peñuela, Benneworth et al., 2015). Moreover, how individuals perceive organisational conditions reflects an evaluation of how a change in the organisational settings might influence research activities and are therefore relevant in influencing the research impact orientation (Dabic et al., 2015).

Among the various individual and organisational determinants of research impact orientation above mentioned, this study concentrates on individual experience, type of organisation, attitudes towards the research activities and perceptions on the

organisational conditions (see Figure 4.2) to understand how an individual researcher performs activities to pursue impact orientation.

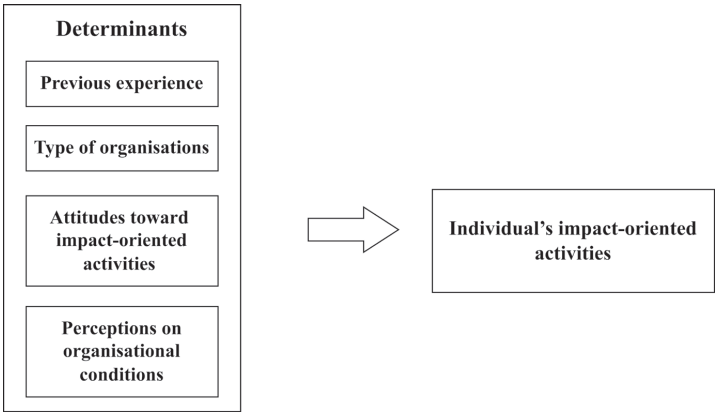

Figure 4.2 The determinants of individual's impact-oriented activities

4.3 Empirical strategy

The study aims to analyse what determinants at individual and organisation level explain how agricultural researchers engage in impact-oriented activities. The main hypothesis of this study is that professional experience, the type of organisation the researchers work for, attitude on impact-oriented activities and perceptions on the organisational conditions are determinants which explain the existence of different groups of individual researchers who perform different research activities.

In order to achieve this aim, first researchers were grouped according to their engagement in research activities. An exploratory factor analysis (EFA) was run to group the activities performed by different researchers into three main groups, which reflected respectively their aims in relation to an interactive (rather than linear) research approach: to produce knowledge with stakeholder involvement, to transfer new knowledge to various groups of users via different approaches and channels, and to be involved in policy processes.

A cluster analysis was then conducted to identify groups of researchers based on the three major groups of activities identified. Finally, a regression analysis was run to understand what individual and organisation characteristics might explain the fact that researchers belong to different groups. Among these determinants, researchers' professional experience in (rice) research and the type of organisations they work for, as well as attitudes towards impact-oriented activities and perceptions on supportive organisational conditions, are considered in this study as relevant predictors.

The professional experience of a researcher is related to participation in impact-oriented activities. The literature has found that post-tenure researchers are likely to engage in more various activities than pre-tenure researchers (Haeussler and Colyvas, 2011). In many cases, senior researchers have already established their reputations and accumulated more human and social capital, which often guides and shapes their activities to pursue impacts of their research. Furthermore, the type of organisations researchers work for mirrors different organisational and management models. According to Haeussler and Colyvas (2011), activities such as technology transfer and commercialisation are conducted differently when the researchers are employed at university compared to public research organisations. In this study, the attitude towards impact-oriented activities focuses on how researchers engage with stakeholders and provide information and knowledge for users. As such, the set of attitudes includes a focus on collaboration with research stakeholders (Neef and Neubert, 2010; McNie et al., 2015; D'Este et al., 2015). The organisational conditions are likely to influence the extent to which researchers perceive the support provided by their organisational settings (D'Este et al., 2015). The supporting organisational conditions were constructed according to the climate within the researchers' working environment that supports more impact-oriented research activities. On the other hand, the limitations on research infrastructures and financial support, as well as difference in organisational cultures, norms and administrative systems, can be a barrier for the impact orientation of researchers.

4.4 Methodology

4.4.1 Data collection and samples

The study used a combination of in-depth interviews and an online questionnaire survey. The key informants of the in-depth interviews were senior researchers in research organisations and universities (in total, 20 interviews). The sample of the online survey consisted of researchers (756) randomly identified by means of a CV search on their organisations' websites in public universities and public research organisations who carried out research related to rice during the period 2008-2017 as listed by the database on agricultural R&D delivered by the National Research Council of Thailand (NRCT). Researchers with no experience in participating in rice research projects and thus not tenured were excluded from the sample selection. The respondents were 119 in total, representing a 16% response rate. The descriptive statistics of the sample of the online survey are reported in Table 4.2.

The interviews aimed to obtain information on the activities, attitudes and perceptions of the researchers and to explore and test questions to ask through the online survey. Following the interview and its preliminary analysis, an online questionnaire survey was structured and implemented from April-June 2019. The online questionnaire focussed on impact orientation at individual and organisational levels and covered three sections in particular: attitudes toward impact-oriented activities, activities of researchers aimed at generating impacts and perceptions on supportive organisational conditions. Statements on attitudes toward their research activities were measured on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) for a level of agreement of the researcher on each statement. Secondly, the set of research activities performed in conducting research and transferring knowledge to society was measured on a Likert scale ranging from 1 for rarely operating (1-20% of overall activities) to 5 for always operating (81-100% of overall activities). When activities were not performed, the statement 'does not operate' was indicated with value 0. Finally, to make sense of their perceptions towards organisational conditions, researchers were asked to assess whether a provided list of organisational conditions was considered as supportive of connecting research to society. A Likert scale ranging from 1 (strongly

disagree) to 5 (strongly agree) was used, with 0 indicating that a specific condition was not applicable to their organisations. The final sample included both public research organisations and universities with 52 and 76 researchers, respectively. Among the respondents, 70% reported 1-10 years of experience in research, 18% about 11-20 years, 6% about 21-30 years and 6% about 31-40 years of experience.

The respondents mainly worked on crop production technology (63 respondents, 49%,); agro-industrial research (53 respondents, 41%); postharvest technology and management (49 respondents, 39%); variety improvement (46 respondents, 36%); molecular biology, genomics and genetics (14 respondents, 11%); economics and marketing management (10 respondents, 8%); public policy (14 respondents, 11%); geo-informatics (8 respondents, 6%) and others (e.g. expert system, biochemical toxicology) (2 respondents, 2%) (Table 4.1).

Table 4.1 Characteristics of participants

Characteristics	No. of responses	% of total no. of responses
Age (years)		
< 36	20	15.63
36-45	59	46.09
46-55	31	24.22
56-65	18	14.06
Highest education		
Bachelor	2	1.56
Master	43	33.59
Doctoral	83	64.84
Organisational type		
University	76	59.38
Public research organisation	52	40.63
Experience in rice research (years)		
1-10	89	69.53
11-20	23	17.97

Table 4.1 (continue)

Characteristics	No. of responses	% of total no. of responses
21-30	8	6.25
31-40	8	6.25
Number of projects during 2008-2017		
1-5	85	66.41
6-10	33	25.78
11-15	6	4.69
16-20	2	1.56
>20	2	1.56
Main research topics		
Crop production technology	63	49.22
Agro-industry and food processing	53	41.41
Postharvest technology and management	49	38.28
Variety improvement	46	35.94
Molecular biology, genomics and genetics	14	10.94
Economics and marketing management	10	7.81
Public policy	14	10.94
Geo-informatics	8	6.25
Others (expert system, biochemical toxicology)	2	1.56
Total	**128**	**100.00**

4.4.2 Analytical method

The analysis was conducted using a multivariate model including a principal component factor analysis (PCA), a cluster analysis and a logistic regression analysis. In order to build the dependent variable of the model (namely, the type of research activities performed), a principal component factor analysis (PCA) was conducted to reduce the number of research activities into main factors from which to derive the dependent variable for the analysis. In the PCA, the factors were rotated using Varimax rotation with Kaiser normalisation, an orthogonal rotation procedure to increase interpretability (Field, 2013). A cluster analysis was then conducted to identify groups of researchers which could be clustered around similar activities. Cluster analysis is an interdependence technique that defines groups as suggested by the data, with maximal homogeneity within the groups and maximum heterogeneity between

the groups. In this study, a K-mean clustering technique was used to obtain the cluster centres. The number of clusters was decided by silhouette analysis (Rousseeuw, 1987). The final stage was to identify what determines the impact-oriented activities of the individual. Binary logistic regression models were performed to find the relationship between impact-oriented activities performed by rice researchers and the individual and organisational determinants related to researchers' individual factors including demographic characteristics, attitudes toward impact-oriented activities and perceptions on supportive organisational conditions.

4.4.3 Dependent variables

Initially, a list of impact-oriented activities was compiled that researchers carry out. The principal component analysis returned a three-factor solution based on an eigenvalue (Table 4.2). The first factor identified was named 'involving stakeholders in research': it consisted of four items related to the participation of stakeholders in research, including conducting research for local specific problems, involving stakeholders in the research agenda, collaborating with stakeholders in research and networking with stakeholders. The second factor identified was labelled 'transferring knowledge', which covers four activities focusing on transferring knowledge through various channels, for instance, open literature, patent, licence, on-site demonstration, personal exchange, spin-off creation or formal or informal networks of researchers and knowledge users. The third factor was defined as 'engaging in policy process'. It consisted of five components indicating the engagement of researchers in the policy process by discussing on process, evaluation and planning research with stakeholders, providing input or advice for any stages of the policy-making process and engagement in initiating, monitoring and evaluating policy process.

Based on the three factors, three groups of rice researchers were constructed by using cluster analysis; Group A included researchers who tend to regularly carry out activities for which they engage with stakeholder in research, knowledge transfer and engagement in the policy process (33.59%); Group B included researchers who tend to focus on conducting activities engaging with stakeholder in research (36.72%); and

Group C included researchers who tend to focus on conducting activities in knowledge transfer (29.69%) (Table 4.3).

Table 4.2 Principle Component Analysis: activities of researchers

Factor	Final variables included	Extracted communalities
F1: Engaging stakeholders in research Total variance explained: 27.16%	F1.1 My research focuses on solving a specific problem at the local scale.	0.71
	F1.2 The users (e.g. farmers, firms, policymakers) of my research are involved in my research agenda.	0.72
	F1.3 I conduct collaborative research related to rice with users (e.g. farmers, firms, policymakers).	0.81
	F1.4 I exchange knowledge on rice through knowledge networks of researchers and stakeholders.	0.56
F2: Transferring knowledge Total variance explained: 19.99%	F2.1 My research is defined by the context of use.	0.52
	F2.2 I transfer knowledge or research output of rice research through media and publishing.	0.50
	F2.3 I transfer knowledge or research output of rice research through licensing.	0.47
	F2.4 I transfer knowledge or research output of rice research by developing/improving techniques, approaches, and/or developing policy implications.	0.83
F3: Engaging in policy process Total variance explained: 16.25	F3.1 I organise meetings with stakeholders (e.g. farmers, NGOs, extension officers, local authorities) to discuss the research process, evaluate outcomes and plan further steps.	0.52
	F3.2 I engage in policy setting in process of advising or discussing policy agendas.	0.77
	F3.3 Result of my research on rice is used for policy-making process at different levels.	0.78
	F3.4 I participate in initiating policy dialogues related to rice.	0.86
	F3.5 I engage in policy monitoring and evaluating policy.	0.90

Remark: Extraction method: principal component analysis Rotation method: Varimax Kaiser normalisation. Only factor loadings greater than 0.3 are displayed.

4.4.4 *Independent variables*

The independent variables of this study are work experience, type of organisation, attitudes toward impact-oriented activities and perceptions on supportive organisational conditions. In order to be concise, these variables' operational definitions and descriptive statistics are presented in Table 4.3.

Professional experience: the professional experience of researchers refers to the year of experience conducting rice research. This variable is a continuous variable ranging from 1-4, (1 for 1-10 years, 2 for 11-20 years, 3 for 21-30 years, 4 for 31-40 years). The average work experience of researcher score is 1.49, with higher scores meaning higher experience in conducting rice research.

Type of organisation: This is captured using a binary variable which takes a value of one (40.63%) if a researcher works for public research organisations, zero if a researcher works at a public university (58.37%).

Attitudes toward impact-oriented activities: researchers' attitudes towards research activities consist of points of view related to the engagement of stakeholders in research processes and to the roles of researchers in impact-oriented activities. Statements were assessed on a 5-point Likert scale aimed at collecting attitudes: collaboration with stakeholder enhances the relevance of research, relevance of research should be defined by users, understanding needs of users makes research credible, disseminating knowledge is researcher's responsibility, and roles of researchers in policy process should be increased (Table 4.3).

Perceptions on supportive organisational conditions: statements related to how researchers experienced and perceived existing supportive conditions in their organisations were assessed on a Likert scale ranging from 0 to 5. Statements were assessed on a 5-point Likert scale that aimed to collect researchers' perceptions about the supportive conditions of their organisation, such as facilitating research in field studies, having experience in commercial activities, supporting entrepreneurial activities, implementing the IP management scheme, encouraging collaborative work with the private sector and limitations in organisations on creating and transferring knowledge (Table 4.3).

Table 4.3 Definitions and descriptive statistics of the independent variables (individual factors) and dependent variable (researchers' impact-oriented activities)

Items	Description	Descriptive statistics
Dependent Variables		
Group A	Coded '1' if the researcher is categorised in the Group A, otherwise '0'	33.86%
Group B	Coded '1' if the researcher is categorised in the Group B, otherwise '0'	37.01%
Group C	Coded '1' if the researcher is categorised in the Group C, otherwise '0'	29.92%
Independent Variables		
Work experience	No. of years experience in rice research ranged: 1-4, (1 for 1-10 years, 2 for 11-20 years, 3 for 21-30 years, 4 for 31-40 years)	Mean: 1.49
Type of organisation	Coded '1' if researcher works in public research organisation and 0 if researcher works in public university	Code 1 = 40.63%, Code 0 = 59.38%
Attitudes toward impact-oriented activities		
- Enhancing relevance of research by collaborating with stakeholder		Mean: 4.42, S.D: 0.69
- Defining relevance of research by users		Mean: 3.65, S.D: 1.15
- Making research credible by considering users' needs		Mean: 4.31, S.D: 0.92
- Disseminating knowledge is researchers' responsibility		Mean: 4.05, S.D: 0.93
- Increase researchers' role in policymaking process		Mean: 4.35, S.D: 0.75
Perception on supportive organisational conditions		
- Facilitating research across field studies		Mean: 3.15 S.D: 1.45

- Experiencing commercial activities	Mean: 1.90 S.D: 1.39
- Supporting entrepreneurial activity	Mean: 1.24 S.D: 1.59
- Implementing IP management scheme	Mean: 3.84 S.D: 1.44
- Using incentive schemes to encourage work with private sector	Mean: 2.79 S.D: 1.29
- Limitation on research infrastructure	Mean: 3.69 S.D: 1.07
- Limitation on financial support	Mean: 3.95 S.D: 1.04
- Limitation on organisational structure	Mean: 3.91 S.D: 1.08

4.5 Results

4.5.1 Classification of rice researchers based on the degree of engagement in impact-oriented activities

Table 4.4 presents the profile of each group in which rice researchers in Thailand can be grouped based on the impact-oriented activities carried out. The activities are categorised into three groups including involving stakeholders in research (F1.1-F1.4), transferring knowledge (F2.1-F2.4) and engaging in policy process (F3.1-F3.5).

Researchers in Group A are characterised by high engagement in the activities of engagement stakeholders in research (average score of 3.71 on a 5-point Likert scale), knowledge transfer (average score of 3.39 on a 5-point Likert scale) and engagement in policy (average score of 3.00 on a 5-point Likert scale). These researchers tend to focus on solving research problems at a local scale, for which they use their own knowledge and involve stakeholders (e.g. farmers, NGOs, extension officers, local authorities) in the process of research and agenda-setting. They transfer knowledge and technology in different ways, including communication through media, licensing and by developing/improving techniques, approaches and policies. Meanwhile, they also contribute to the policymaking process through various activities, such as discussing research processes, evaluating outcomes and planning further steps with stakeholders, advising or discussing on policy agendas, providing input for

policymaking processes, participating in initiating policy dialogues and being involved in policy monitoring and, finally, evaluating policy.

In addition, researchers in Group B perform activities aimed at engaging with stakeholders in research (F1.1-F1.4) to a high degree. The overall average score is 3.38 on the Likert scale of 5). Similar to the researchers in Group A, the researchers in Group B always conduct research focussed on solving a specific problem in local context. They transfer knowledge or research output of rice research mainly through one-way communication, e.g. media and publishing (all of them are above the neutral point of 2.50 on the Likert scale of 5). Nevertheless, they infrequently transfer knowledge via licensing and by developing new techniques, approaches and/or policies. Also, they are rarely involved in policy process (all of them are below the neutral point of 2.50 on the Likert scale of 5).

Finally, Group C consists of researchers who seem to assess the activities with the lowest score. Among the three groups of activities, the score for knowledge transfer activities being just above average (2.5 on the Likert scale of 5) could imply that researchers in Group C consider that they conduct knowledge transfer activities (F2.1-F2.4) more than activities related to engaging with stakeholders and with policy processes. They mainly transfer knowledge and technology via media and by developing techniques, approaches, and/or policy implications of their research. They tend to carry out research to solve local problems and define the context of use of their research, as indicated by the score for these activities closed to a neutral value (on a scale from 1 to 5). However, these researchers infrequently involve stakeholders in their research and rarely engage in policy processes.

In summary, the results showed that among the three groups of researchers, researchers in Group A tend to perform at the same time various activities related to the three groups of activities identified, namely involving stakeholders in research, transferring knowledge and engagement in policy process (all of them are above the neutral point of 2.50 on a Likert scale of 5). Researchers in groups B and C likely conduct the three groups of activities at a lower degree compared to Group A. Both Group B and C seem to rather focus on conducting one group of activities, respectively

involving stakeholder in their research and technology transfer. The radar chart (Figure 4.3) illustrates the groups of researchers based on the degree of engagement of the researchers in the three main impact-oriented activities.

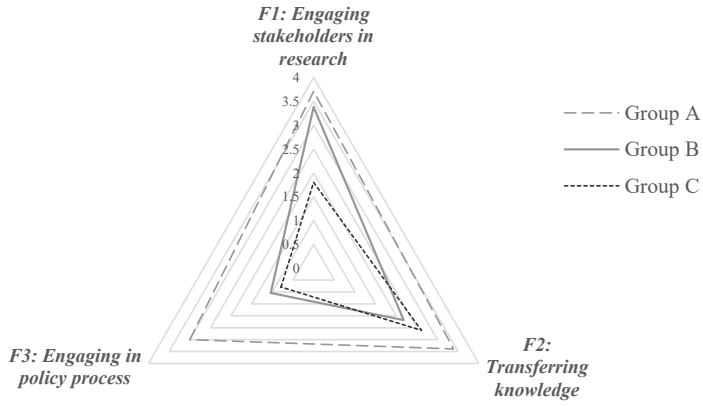

Figure 4.3 Group of researchers by degree of engagement in three activities

Table 4.4 A range of research activities of each group of researchers

Factors	Group		
	A	**B**	**C**
F1: Engaging stakeholders in research	*3.71*	*3.38*	*1.80*
F1.1 My research focuses on solving a specific problem at the local scale.	4.00±0.76	4.06±0.89	2.42±1.33
F1.2 The users (e.g. farmers, firms, policymakers) of my research are involved in my research agenda.	3.47±1.16	3.26±1.29	1.45±1.45
F1.3 I conduct collaborative research related to rice with users (e.g. farmers, firms, policymakers).	3.72±0.85	3.36±1.26	1.42±1.18
F1.4 I exchange knowledge on rice through knowledge networks of researchers and stakeholders.	3.65±0.97	2.83±0.97	1.89±1.45
F2: Transferring knowledge	*3.39*	*2.18*	*2.61*
F2.1 My research is defined by the context of use.	3.37±0.93	3.02±0.93	2.82±1.39
F2.2 I transfer knowledge or research output of rice research through media and publishing.	3.67±1.04	2.87±1.55	2.79±1.40
F2.3 I transfer knowledge or research output of rice research through intellectual property rights.	2.74±1.83	0.40±1.01	1.55±1.95
F2.4 I transfer knowledge or research output of rice research by developing/improving techniques, approaches, and/or developing policy implications.	3.79±1.08	2.43±1.08	3.26±1.31
F3: Engaging in policy process	*3.00*	*1.04*	*0.79*
F3.1 I organise meetings with stakeholders (e.g. farmers, NGOs, extension officers, local authorities) to discuss the research process, evaluate outcomes and plan further steps.	3.26±0.95	1.98±1.38	1.18± 1.31
F3.2 I engage in policy setting in the process of advising or discussing policy agendas.	2.95±1.21	0.98±1.38	0.74±1.08
F3.3 Result of my research on rice is used for policy-making process at different levels.	3.26±1.05	1.15±1.41	0.92±1.12
F3.4 I participate in initiating policy dialogue related to rice.	2.70±1.21	0.60±0.88	0.21±0.47
F3.5 I engage in policy monitoring and evaluating policy	2.81±1.05	0.49±0.86	0.39±0.79

Remark: Likert scale 0=do not/never operate (0%), 1=rarely operate (1-20%); 5=always operate (81-100%)

4.5.2 *Determinants of impact orientation among rice researchers*

A binary logistic regression was conducted to examine the relative importance individual and organisational determinants in explaining the difference in the research activities in which researchers engage. The results of logistic regressions are reported in Table 4.5.

The first model (Model A) investigated the determinants at individual and organisational level of the fact that researchers tend to carry out both activities in engaging stakeholders in research, knowledge transfer and engagement in the policy process very regularly (Group A). Considering factors related to professional characteristics, both work experience and working in public research organisations seem to be good predictors of researchers being in Group A. When looking at the attitudes toward research activities, the fact that researchers value the societal relevance of their research very much presents a positive and statistically significant association with researchers being in Group A. However, researchers in Group A seem not to consider that addressing users makes research more credible. This result is somewhat intuitive, as the respondents in Group A pointed out that agenda-setting for research projects is always practiced by funding agencies with a little involvement of stakeholders. When looking at attitudes towards organisational conditions, having experience on commercial activities is likely to positively predict the fact that researchers belong to Group A. On the other hand, the implementation of IP scheme shows a negative and significant association with researchers in Group A. Besides, the limitations related to organisational structure present a negative association with the activities of researchers in Group A.

The second model (Model B) investigated the determinants of researchers belonging to Group B. Work experience seems not to be a predictor of a researcher being in Group B. Instead, knowledge dissemination (expressed by the statements: 'the needs of users make research credible' and 'disseminating knowledge is the researcher's responsibility') is found to positively associate with researchers in Group B. However, the perception of their organisation's experience on commercial activities presents a negative relation with the researchers being in Group B. Researchers in Group B also

believe that the existing funding mechanisms and organisational conditions do not facilitate collaborative research with both researchers from different study areas and stakeholders.

Model C investigated finally the determinants associated with the researchers categorised in Group C. Results seem somewhat counterintuitive. Although researchers are likely to perform activities such as transferring knowledge or research output through media and publishing and/or by developing/improving techniques, approaches or policies, results seem to indicate that knowledge dissemination (i.e. expressed in terms of 'disseminating knowledge is researcher's responsibility') is negatively associated with their activities. Working in a public research organisation seems to negatively influence the activities of the researchers in this group. The researchers' perception regarding an incentive system possibly encouraging to work with the private sector also shows a negative influence on researchers conducting their activities.

Nevertheless, researchers in this group believe that the implementation of intellectual property management schemes in their organisation is supportive of their operation, as the related variable indicates, having a positive relationship with researchers in Group C.

Table 4.5 Logistic regression of the factor associating different degrees of engagement in impact-oriented activities

Independent variables	Model		
	A	**B**	**C**
Work experiences	3.60*** (0.000)	-2.46** (0.014)	-1.51 (0.131)
Attitudes toward impact-oriented activities			
- Collaboration with stakeholder enhances relevance of research	-0.67 (0.505)	-0.67 (0.502)	0.84 (0.402)
- Research user defines relevance of research	3.23** (0.001)	-1.45 (0.146)	-1.83 (0.067)
- Considering users' needs makes research credible	-3.17** (0.002)	2.51** (0.012)	0.97 (0.330)
- Disseminating knowledge is researchers' responsibility	0.51 (0.612)	2.31* (0.021)	-0.44** (0.015)
- Increase researchers' role in policymaking process	1.25 (0.211)	-0.94 (0.349)	0.22 (0.826)
Type of organisations	2.03* (0.042)	0.39 (0.694)	-1.98* (0.048)
Perception on supportive organisational conditions			
- Facilitating research across field studies	0.24 (0.812)	-1.24 (0.216)	0.55 (0.585)
- Experiencing commercial activities	3.05** (0.002)	-2.06* (0.040)	-1.43 (0.153)
- Supporting entrepreneurial activity	0.95 (0.342)	-1.15 (0.251)	-0.09 (0.927)
- Implementing IP management scheme	-2.04* (0.041)	0.02 (0.982)	2.33* (0.020)
- Using incentive schemes to encourage work with private sector	1.22 (0.223)	1.05 (0.292)	-1.99* (0.047)
- Limitation on research infrastructure	1.95 (0.052)	-1.05 (0.295)	-1.12 (0.264)
- Limitation on financial support	-0.44 (0.662)	0,26 (0.797)	0.51 (0.612)
- Limitation on organisational structure	-2.17* (0.030)	0.29 (0.773)	1.82 (0.068)
Constant	-1.68 (0.092)	-0.63 (0.531)	0.68 (0.497)
Pseudo R^2	0.3885	0.2270	0.2601
Prob > chi2	0.0002	0.0008	0.0004

Remark: *, ** and *** indicate that the variable is significant at the 10%, 5% and 1% levels, respectively

4.6 Discussion

The objective of this study was to provide insights on how differently researchers engage in impact-oriented activities based on characteristics, type of organisation, attitudes toward impact-oriented activities and perceptions on supportive organisational conditions. The analyses carried out on a sample of rice researchers in Thailand indicate that they mainly perform activities related to engaging stakeholders in their research and the dissemination of knowledge and technology. When asked about their activities in the policy process, researchers seemed to perform them to a lesser extent. In fact, rice research in Thailand has been conducted mainly in areas such as technology development, such as crop production technology, agro-industrial technology, postharvest technology and management and variety improvement, whereas research activities related to policy (e.g. management and public policy) appeared to cover only a minor percentage of rice research in total. It is therefore likely that the research goals of rice researchers and their engagement in different activities and practices differ greatly among different research domains. This observation supports what the previous literature has also suggested, namely that the engagement of researchers in impact orientation activities might vary between the disciplines or research fields in which they are active (Fecher and Hebing, 2021; Olmos-Peñuela et al., 2014; Haeussler and Colyvas, 2011).

The analyses show what determines the allocation of researchers into different groups. Exploring these determinants could provide insights into how individual researchers see their own role and how their organisations might support or restrict their outcomes. We found that experienced researchers tend to engage with various groups of activities, especially those contributing to policymaking, more than less experienced ones. This is in line with studies that analyse the influence of researcher's characteristics on impact-oriented activities (see D'Este et al., 2018; Fecher and Hebing, 2021; Olmos-Peñuela et al., 2015; Haeussler and Colyvas, 2011), which indicate that experienced researchers might be able to access extended social capital networks thanks to their experience working in different sectors, including strengthening connections with stakeholders (D'Este et al., 2018). The results reflect that more

experienced researchers are able to engage with various activities. Being experienced might help researchers to be well positioned to influence policy decision-making (Fecher and Hebing, 2021).

Evidence shows that attitudes towards impact orientation activities are associated with each group of researchers differently. A positive attitude toward setting a research agenda in cooperation with stakeholders tends to influence awareness of the demands to which researchers can contribute and the mechanisms for achieving these objectives (D'Este et al., 2018). This could imply that among agricultural researchers attitudes towards stakeholder participation in research might diverge. Although an increasing number of researchers see addressing localised problems and knowledge dissemination to stakeholders as crucial components in the impact-generating process, some researchers tend to regard them as irrelevant for formal agricultural research (Neef and Neubert, 2011).

The rice researchers who work in public research organisations are more likely to be involved in the three types of research activities than researchers in universities. This would be explained by the fact that university researchers have teaching and lecturing obligations which are not mandatory at public research organisations and, therefore, the university researchers have less time for engagement activities. One of the reasons that respondents reported in our case study is that public universities in Thailand frequently use the number of publications to demonstrate academic quality to peers as key performance indicators, while public research organisations tend to focus more on knowledge production for practical use by involving stakeholders in research. This study brings to the fore the suggestions of Dabic et al. (2015) concerning the existence of several different types of attitudes towards the organisational conditions. In this study, organisational conditions were likely assessed in bottom-up performance evaluation. The perception on supportive organisational conditions could be interpreted in the sense of personal satisfaction or accessibility of organisational conditions. In Thailand, rice research is predominantly conducted by public research, namely public research organisations and public universities. The output of public research is conceptualised as public goods; the production of knowledge in public

settings has always been highly secretive, exclusionary and often intended for practical application (Haeussler and Colyvas, 2011). The findings add weight to the organisational features related to commercial research, intellectual property management and collaboration with private sector in the public research organisations and public universities as they foster the connection between researchers and societal actors who potentially could participate in and benefit from knowledge exchange processes (D'Este et al., 2018; Siegel and Wright 2015).

4.7 Conclusions and implications

Evidence from the case study of rice researchers in Thailand shows that it is possible to identify three different groups of researchers based on the activities related to the impact orientation of their research. The involvement of stakeholders in research, especially research users, emerged in different forms, for instance, conducting research in response to local problems, involving research users in research agenda, collaborating with research users and exchanging knowledge through networks of researchers and stakeholders. Knowledge dissemination was conducted via media and publishing. In addition, knowledge or research outputs led to learning processes in the form of development of techniques, approaches and policy implications. The factors including work experience, types of organisation, attitudes towards impact-oriented activities and perceptions on supportive conditions in organisations were identified as determinants of the different degree of engagement in impact orientation practices of researchers. This research also shows that organisational support to collaboration on research and knowledge transfer is necessary. This study could bring additional insights on different attitudes towards impact orientation and perceptions on organisational conditions among researchers with different degree of engagement in impact-oriented activities.

Understanding the heterogeneity of researchers based on engagement in impact-oriented activities is helpful in a variety of efforts, including employee selection and training. Organisational supportive conditions and incentives are suggested to pay more attention to facilitating and strengthening different kinds of interaction with

stakeholders rather than only the volume of research output. Some limitations of this study that could provide directions for future research are noted here. First, the information on attitudes toward impact-oriented activities, activities of researchers aiming at generating impacts and perceptions on supportive organisational conditions, rely on self-assessment survey information. The respondents may interpret the statements differently according to their knowledge, experience and field of study. The wording used in the questionnaire may be confusing for the respondents, probably due to the gap between theoretical/conceptual framework and evidence. Background information on the existing components of the rice research system can be more helpful in comprehensively constructing the questionnaire. The results can be more extensive when researchers are asked with a qualitative approach about the details of how they think and conduct their microscale research practices and how they see the way their organisation could support them in doing so. Finally, this study focuses on only the determinants related to individual researchers and their organisations. However, the funding mechanisms and expectations also affect impact orientation at the organisational and individual level, respectively. Future research could include determinants related to funding mechanisms and expectations in the analysis, such as accessibility to or attitudes of individual researchers towards funding mechanisms.

Chapter 4

Chapter 5

Exploring the role of research program leaders in enhancing the impact of the Riceberry research programme: Combining functional approach with impact pathway analysis

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Abstract

To ensure the impact of agricultural research, several approaches and methodologies have been developed to gain insight into the impact-generating mechanisms. This study explores the roles and functions performed by individual researchers in facilitating the development, diffusion and use of knowledge and technology by combining a functional analysis with an impact pathway analysis. We use the case of the Riceberry research programme in Thailand to explore and implement our approach. The combination of functional analysis with impact pathway analysis is useful to capture the role of programme leaders as system builders in contributing to fostering innovation system functions through research activities. Moreover, the combination of functional analysis with impact pathway analysis reveals the visibility of the programme leaders' de facto work on a package of interdependent technical, organisational and institutional innovations rather than on a single innovation. This finding can certainly be relevant in developing countries where the research system appears to have weak institutional arrangements and lacks incentives to contribute to the impact on society. The approach can be further developed for ex post analysis of impact generation trajectories and the ex-ante formulation of impact strategies.

Keywords: impact evaluation, functions of innovation system, impact pathway, agricultural research, system-building processes

5.1 Introduction

Both agricultural research organisations and their funding agencies are expected to ensure that their research contributes to development and change in society. In this context, there is considerable interest in topics related to assessing the impact of research efforts. While numerous studies focus on whether or not particular types of impacts (e.g. economic, social, environmental) occur (Hazell, 2008; Maredia and Raizer, 2012; Weißhuhn et al., 2018), we also witness considerable interest in understanding the processes through which agricultural research may generate impact. A better understanding of the way in which research-based technologies are assimilated, diffused and utilised can offer guidance for agricultural researchers and others involved in ensuring that society benefits from research output (Manyong et al., 2001).

Several approaches and methodologies have been developed to gain insight into the mechanisms through which research may contribute to impact (Woolcock 2009; Donovan 2011; Spaapen and Van Drooge, 2011; Joly et al., 2015; Matt et al., 2017). Many of these methods are inspired by innovative systems-thinking (Hall et al., 2003) and emphasise the need of understanding the complex and multiple interactions that occur between a range of actors (researchers, intermediaries, users, private sector, policymakers, etc.) in processes of generating impact. In order to capture this complexity, some approaches and studies focus on how research(ers) contribute to enabling the functions in technological innovation systems (TIS) that are known to be important in shaping the development, diffusion and use of a particular technology (Hekkert and Negro, 2009; Berge et al., 2008; Hellsmark & Jacobsson, 2009; Perez Vico, 2014). Other studies and approaches unravel the process through which research may generate impact with the help of ex post impact pathway analysis (Joly et al., 2015; Faure et al., 2018), oriented to reconstructing how research inputs result in research outputs and how these subsequently help foster outcomes and impacts in society. Both types of approaches have yielded useful insights in the mechanism through which research may contribute to impact but so far have not been combined or integrated. A common finding across studies conducted through various lenses and methods is that

individual researchers and/or research programme leaders can play pivotal roles and perform various functions in facilitating development, diffusion and use of knowledge and technology (Faure et al., 2018; Joly et al., 2015; Hellsmark & Jacobsson, 2009; Basu & Leeuwis, 2012; Perez Vico, 2014). Such roles may relate to different TIS functions, e.g. resource mobilisation, legitimation, guidance of the search (see Hellsmark & Jacobsson, 2009), and vary from the transfer and dissemination of research findings among different actor groups, to focusing on facilitating joint knowledge production and learning with or among actors involved (Schut et al., 2011; Faure et al., 2018). Similarly, researchers can be involved in lobbying and advocacy activities that contribute to network and coalition formation around specific innovations (Basu and Leeuwis, 2012). In connection with such findings, researchers have been described as 'system builders' (Hellsmark & Jacobsson, 2009; Perez Vico, 2014) or 'innovation champions' (Shambu Prasad, 2006; Klerkx et al., 2010). We can assume that the role of such individuals can certainly be relevant (or even more pronounced) in developing countries where institutional arrangements tend to be weak and where incentives to contribute to impact in society are not always in place (Gijsbers and van Tulder, 2010; Bryerlee, 1998).

As further elaborated in the following, this study aims to provide more detailed insight into the roles that research programme leaders may play in contributing to social impact by combining a functional analysis with an impact pathway analysis. The combined approach allows us to further specify and also visualise researcher activities and function formation as part of an unfolding series of events that cuts across several generations of projects. We use the case of the Riceberry research programme in Thailand to explore and implement our approach. This programme is known to have generated a high impact in boosting the uptake of a new black-coloured rice grain in Thailand and beyond. The programme leader, Professor Apichart Vanavichit, acted as researcher and programme manager and played a central role in responding to challenges and in coordinating transformation activities oriented to achieving impact along a series of projects that were carried out over a fifteen-year period.

The paper proceeds with a description of the analytical framework (Section 2) which is followed by an explanation of our methodological strategy (Section 3). Section 4 focusses on the chronological development of Riceberry research programme and details how researcher activities within the research programme are linked to the performance of TIS functions along three interconnected impact pathways, corresponding with three different phases in the programme. The findings and their implications are discussed in Section 5. The paper ends with a short conclusion on the findings and the value of combining a functional perspective on impact generation with impact pathway analyses.

5.2 Analytical framework

Below we discuss two analytical lenses that have been used to analyse the role of research in processes of generating impact.

5.2.1 Focusing on functions of technological innovation systems

A technological innovation system (TIS) is seen as being composed of a set of structural elements: technologies, actors (e.g. public, private, research, users), networks, institutions (regulations, norms, cognition) and technologies (e.g. Malerba, 2004; Suurs and Hekkert, 2009; Hellsmark and Jacobsson, 2009). These elements are seen to interact with each other and can form a coherent and innovation-supporting whole if particular functions are performed. Innovation system scholars have identified seven key processes or functions: knowledge development and diffusion, entrepreneurial experimentation, influence on the direction of search, market formation, development of positive external economies, building up legitimacy and resource mobilisation (Hekkert et al., 2007; Bergek et al., 2008). Thus, the functional approach highlights the process dimension of innovation systems as a complement to the identification of structural elements. This perspective is typically used to assess whether the collective and aggregated 'activities' that innovation actors are engaged in result in a proper performance of the various functions (see also Table 5.1) (Bergek et al., 2008; Hekkert et al., 2007). The perspective has been used in relation to different technological and sectoral innovation systems (Negro et al., 2006; Dewald and Truffer, 2012; Markard et al., 2016; Turner et al., 2015; Lamprinopoulou et al., 2014) and is often applied to study

the emergence, growth and performance of new technological fields. It has also been applied successfully to study performance and system dynamics across time and space (Alkemede et al., 2007; Hellsmark and Jacobson, 2009; Lamprinopoulou et al., 2014) as well as across different market and/or value chain segments and substructures (Dewald and Truffer, 2012).

In essence, studies that use the functional approach to enhance the understanding of the role of research(ers) in processes of impact generation map the contributions of research onto the development of function of a TIS (Jacobsson and Vico, 2010; Vico and Jacobsson, 2012; Jacobsson, Vico and Hellsmark, 2014). In doing so, it is important to somehow link activities of researchers to innovative system functions. In some cases, the linkage between activities and functions can be obvious; for instance, an activity like 'conducting research' typically impacts on the function 'knowledge development and diffusion'. However, the same activity may also strengthen other functions (e.g. guidance of the search, see for example Neef and Neubert, 2010; Humphries et al., 2015) and thus the precise relations must be empirically assessed. This is also true for the activities that researchers carry out. Some studies focusing on research impact tend to focus on a limited range of formal activities that are officially recorded by the organisation in formal agreements (Olmos-Peñuela et al., 2014). However, it is widely recognised that agricultural researchers can play a wide range of roles in innovation processes (e.g. they can operate as experts, trainers, coordinators, facilitators and also as observers or learners themselves, see Faure et al., 2018) and several such roles and activities may not be officially documented or recognised (see e.g. Gildemacher et al., 2012). Thus, it is important to also look for less visible and informal activities (e.g. informal consultations, see Abreu et al., 2009; Druilhe and Garnsey, 2004) which can usefully complement or be a precursor to more formal engagement (Grimpe and Hussinger, 2008).

In this study, we start from a classification of research activities and process functions as described by Jacobsson and Vico (2010) (see Table 5.1).

Table 5.1 Research activities and the functions of innovation

Research activities	Function of technological innovation system
Conducting research in different types of set-ups, for example through joint R&D projects or contract research and intra-academic research projects. **Scientific publishing** refers to the academic form of diffusing information through papers, books and reports, including related tasks such as reviewing and editing. **Educating** includes undergraduate, Masters and PhD student training, as well as collaborative and contract training for policy and industry. **Providing explicit guidance** to policy and industry involves formal and informal consultations and assignments, such as participation in advisory boards and informal advisory work. Guidance also includes participation in public debates by publishing in non-scientific publications, by media appearance and by giving public seminars. Guidance includes guidance on social and economic issues connected to technical	**Influence on the direction of search** is the process by which new actors are attracted to and directed within a system by for example visions, perceived growth potential, policy incentives, technical breakthroughs or bottlenecks, requirements from leading customers or business crises. **Legitimation** is a process influenced by socio-political actions creating acceptance and attractiveness for a technology, application or industry. This implies overcoming liability of newness and acquiring political strength. **Market formation** includes the development process of niche, bridging and mass markets. This evolves as customers articulate their demand or as companies introduce market-changing products. **Entrepreneurial experimentation** includes the development of new opportunities and applied knowledge through testing of new concepts, applications and markets. It implies

choices, as well as providing frameworks and empirical underpinnings of policy. Guidance may also be given within the research community. **Commercialisation** refers to the creation of new firms, patents, licences, products, processes and services. **Providing research infrastructure** involves developing and maintaining instruments, laboratories, clean rooms, libraries, engineering designs and methods, as well as methods of doing research. **Networking** refers to the creation and maintenance of networks. It is an integral part of academic activities and is, for instance, performed through organising and participating in collaborative research, conferences and seminars involving both academic and non-academic actors.	materialisation of knowledge, i.e. developing new products, processes or organisational forms. **Resource mobilisation** relates to financial and human capital as well as complementary assets. **Knowledge development and diffusion** includes the creation, diffusion and combination of knowledge in the system. **Social capital development** is the process by which social relations are created and maintained. These relations include trust, dependence, mutual recognition, authority and shared norms. This process enables system-level activities, such as the build-up of networks and collective actions.

Source: Bergek et al., 2008; Jacobsson and Perez Vico, 2010; Perez Vico, 2014

5.2.2 Impact pathway analysis

Another approach that applies innovation system thinking to enhance our understanding of the role of research in impact generation is impact pathway analysis (Blundo Canto et al., 2018; Joly et al., 2015, Faure et al., 2018; Quiedeville, 2017).

Interventions (including research interventions) geared towards achieving societal goals are often asked in advance to formulate an impact pathway (or very similar: a 'theory of change' (ToC), see Thornton et al., 2017) that unpacks and visualises the ideas, strategies and assumptions that projects have about how their activities will result in impact. Although such impact pathways and ToC are often formulated ex ante and may be used to monitor and adapt impact generation as it unfolds in real-time (Joly et al., 2015), the way of thinking has also been used to reconstruct impact generation processes after the fact (see Blundo Canto et al., 2018; Doubtwaite et al., 2003).

As shown in Figure 5.1, the basic elements of an impact pathway of agricultural research include 'research inputs' (e.g. resources such as budget, pre-existing knowledge, infrastructure, etc.) and activities that result in 'research outputs' (e.g. the deliverables such as technologies, knowledge, capacities and recommendations). Subsequently, the 'immediate outcomes' refer to how others who are in direct contact with the research intervention ('next users' such as extensionists, policymakers, NGOs and farmers) translate the project results into their work and use them to adapt their practices, strategies and behaviour, assumedly in line with the objectives of the research intervention. This then results in changes in conditions at a greater distance from the research intervention ('intermediate outcomes') that are necessary to achieve the 'intermediate impacts' of the environmental, economic and/or social that the research intervention was aimed at achieving beyond the project's lifespan (Doutwaite et al., 2003; Springer-Heinze et al., 2003; Blundo Canto, 2018; Palis et al., 2013).

The impact pathway model has been widely applied to evaluate impacts, thereby stressing the importance of engaging with relevant stakeholders and interacting with knowledge user communities in several impact assessment approaches (Woolcock 2009; Blundo Canto et al., 2018; Quiedeville et al., 2017). The ASIRPA approach (Socioeconomic Analysis of the Impacts of Public Agricultural Research) complements the impact pathway analysis with information related to productive configurations and uses the concept of contribution to indicate that impact is produced by the network and cannot be broken down into the contributions of individual actors (Joly

et al., 2015). The ex post evaluation method ImpresS (Impact of Research in the South) was inspired by ASIRPA and aims to understand the causal relationships that lead from research activities to societal impacts through a mixed deductive and inductive approach that reconstructs trajectories of change (Woolcock 2009; Blundo Canto et al., 2017).

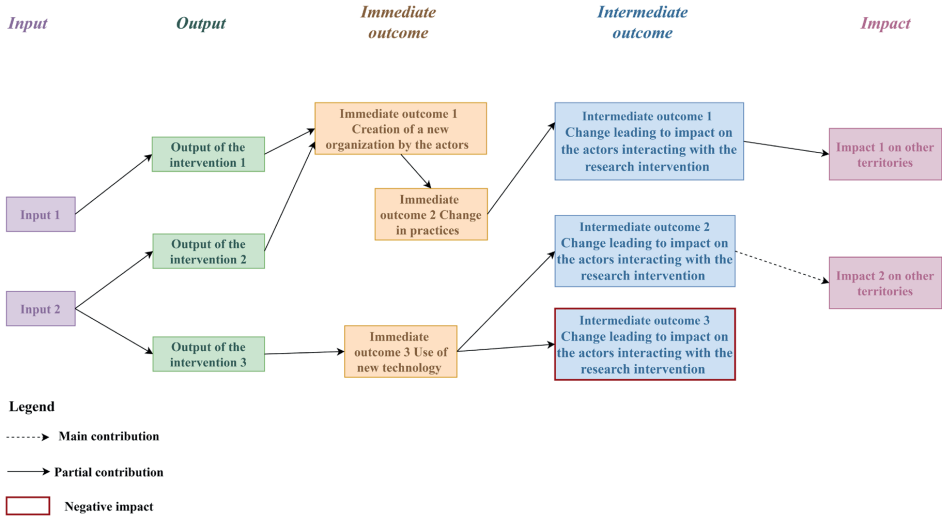

Figure 5.1 Standard elements in an impact pathway analysis
Source: adapted from Blundo Canto et al., 2018

The impact pathway model has been widely applied to evaluate impacts, thereby stressing the importance of engaging with relevant stakeholders and interacting with knowledge user communities in several impact assessment approaches (Woolcock 2009; Blundo Canto et al., 2018; Quiedeville et al., 2017). The ASIRPA approach (Socioeconomic Analysis of the Impacts of Public Agricultural Research) complements the impact pathway analysis with information related to productive configurations and uses the concept of contribution to indicate that impact is produced by the network and cannot be broken down into the contributions of individual actors (Joly et al., 2015). The ex post evaluation method ImpresS (Impact of Research in the South) was inspired by ASIRPA and aims to understand the causal relationships that lead from research activities to societal impacts through a mixed deductive and inductive

approach that reconstructs trajectories of change (Woolcock 2009; Blundo Canto et al., 2017).

While impact pathway analysis links research activity explicitly to activities of others in a chain of events towards impact, it is interesting to note that the activities of researchers are captured most clearly in the early steps of the impact pathway where researchers invest time and other resources (input) to produce certain outputs, whereas their roles and activities are less clearly captured in later stages. When aiming to understand the role of research programme leaders, this is a limitation as it may well be that 'champions' or 'system builders' actively intervene to ensure or support that 'immediate outcomes' lead to 'intermediate outcomes' and subsequently to 'impact' (see e.g. Basu & Leeuwis, 2012; Hallsmark and Jacobsson, 2009; Perez Vico, 2014; Shambu Prasad, 2006; Klerkx et al., 2010).

5.2.3 Combining functional and impact pathway analysis

We have seen that both the functional approach and impact pathway analyses offer opportunities for studying the role of research programme leaders in impact generation. Impact pathway analysis offers opportunities to reconstruct chains of events in a manner that is more systematic and detailed than is often done with the functional approach. The functional approach offers the possibility of giving a broader meaning to the effects of research activity in terms of the systemic functions to which they contribute. In this chapter, we will combine and integrate the two approaches. In doing so, we aim to clarify the role of researchers by specifying and placing researcher activities (as distinguished in the functional approach, see Table 5.1) at the interfaces between inputs, outputs, outcomes and impacts. This means that researchers can take specific actions to support or ensure that an 'output' will translate into an 'immediate outcome' or that an 'immediate outcome' contributes to 'intermediate outcomes' or 'impact'. At the same time we will characterise the various 'inputs', 'outputs' and 'outcomes' in terms of the functions that they are likely to fulfil in the innovation system. In order to clarify the link with different phases and/or sources of funding that occurred over the fifteen-year period of the Riceberry innovation history, we present several interlinked impact pathways whereby the 'outputs' or 'outcomes' in

one phase become 'inputs' for the next phase. The visualisation of the interlinked impact pathway enables us to more clearly see the relations between different research intervention programmes over time and understand 'system-building' as a gradually progressing iterative process.

5.3 Methodology

5.3.1. Data collection

This study aims to provide a detailed account of the contributions of a researcher programme leader to the direct and indirect impacts of agricultural research. The case study method was chosen to provide a holistic understanding of the long-term contextual process of impact generation (Perez Vico, 2014). Although a single case study has limitations in terms of generalizability, experience learns that single case studies can yield in-depth understandings of the kind of interactional dynamic that may be involved in impact generation, and that may be of broader relevance, if only to orient further research (Hellsmark & Jacobsson, 2009; Basu & Leeuwis, 2012; Perez Vico, 2014; Kumar, 2014). Moreover, the use of a single case study makes sense in view of the fact that we are exploring a novel approach to combining functional and impact pathway analysis. Data was collected from multiple sources both primary and secondary data sources, including in-depth interviews with key informants, final reports of research programme, research evaluation reports, scientific articles, online documentation and publication databases.

5.3.2. Data analysis

The data was analysed with the help of the concepts discussed in the analytical framework, and events and observations were coded as activities, functions and elements along the impact pathway. The preliminary results, including the timeline of the research programme and the activities and interventions that researchers carried out during the research programme, were validated through in-depth interviews with key informants. The data analysis was inspired by earlier cases that involved analysis of the role of research activities and how these link to functions (Jacobsson and Vico, 2010; Vico and Jacobsson, 2012; Jacobsson, Vico and Hellsmark, 2014), as well as by

studies that reconstructed impact pathways (Doutwaite et al., 2003; Blundo Canto, 2018; Palis et al., 2013). First, we codified the main data produced in the case study and organised the data around the chronological development of the Riceberry programme. The timelines with important events and research activities were identified using information from final reports, publications and semi-structured interviews. To increase robustness, the timeline was presented to and discussed with the researchers and stakeholders who participated in the case study. The transcriptions of the semi-structured interview and the secondary data were coded with the help of guiding questions such as what activities are conducted, how and by whom, and what functions are influenced or performed through the activities. The impact pathway analysis was constructed by mapping out information collected around the research activities about the type of functions and outcomes that resulted from them, as indicated by interviewees and project documents.

5.4 Results

This section contains a descriptive analysis of the development of Riceberry from the beginning of the research programme in 2004. The analysis is split into two parts. The first section emphasised the development of the Riceberry research programme based on documented or formal activities and interventions, resulting in an understanding of the overall context and time line. The second section covers the detailed description and analyses of activities and functions that were performed throughout the lifespan of the research programme on the path towards impact. Three overlapping impact pathways were constructed to track how activities and functions are linked and influence each other.

5.4.1. An overview of the development of the Riceberry research programme according to official documents

In the context of widespread malnutrition in the main rice consuming countries of the world, breeding programmes have been proposed to increase micronutrient levels in rice to address micronutrient deficiencies (Bouis and Hunt, 1999). The Riceberry research programme was initially developed with the aim of boosting nutritional

values, fragrance and the taste of rice in 2002 and several years of integrated research into its nutritional properties, anthocyanin stability and physical and cooking properties followed (Vanavichit, 2020). The programme leader was Professor Apichart Vanavichit, who is now a Professor in the department of Agronomy at the Faculty of Agriculture at the Kamphaeng Saen Campus of Kasetsart University and also director of the Rice Science Centre in the same university. He participated in the International Collaboration for Sequencing the Rice Genome (ICSRG) in 1998 which led to the discovery of aromatic genes in rice, including a new ideotype rice for organic farming (ref). The Riceberry research programme was funded by the National Research Council of Thailand (NRCT) under the programme title 'Integrated biotechnology in developing rice strains for high-value-added and nutrient enrichment' that was funded from 2004 to 2012 with in total 0.85 million USD (28.5 million Baht). One of the main purposes of the Riceberry research programme was to boost the nutritional value, fragrance and cooking quality of pigmented rice. Professor Apichart therefore sought collaboration with nutrition researchers, which resulted in Dr. Ratchanee Kongkhachuichai of the Mahidol University Nutrition Research Institute becoming one of project leaders. Other enrolled partners include the National Science Technology Development Agency (NSTDA) and the Faculty of Medicine of Ramathibodi Hospital and Chiang Mai University (CMU) (Praneetvatakul et al., 2018).

The Riceberry variety was developed from a cross between two renowned Thai rice strains: Jao Hom Nin (a Thai purple rice) and Khoa Dawk Mali 105 (Thai Hommali rice). The purple and black grain was developed by the programme leader and his team in 2002. The integrated research into its nutritional properties, anthocyanin stability and physical and cooking properties was conducted in parallel. In addition to the Riceberry variety itself, the first phase of research programme generated new knowledge on pigmented rice, rice production systems and the nutritional properties of Riceberry relevant to the food therapy programme (Vanavichit et al., 2005). Through manipulation of the amylose content, Riceberry variety was improved to be soft and have a good cooking quality. The variety is a source of gramma-oryzanol, beta-carotene, niacin, thiamine, vitamin B2, anthocyanins and total phenolic compounds (Leardkamolkarn et al., 2011). The bran extracted from Riceberry was evaluated for

safety in human cancer cell lines from colon, breast and blood (Leardkamolkarn et al., 2011). The Riceberry seed and production techniques were transferred to farmers in Northern Thailand in the cropping year 2009/10 and one year later to farmers in North-Eastern Thailand. This was done by means of extension programmes that were supported by NGOs, government agencies and universities (Praneetvatakul et al., 2018). For instance, with the help of such partners, the Riceberry Valley project has, for instance, been operated in 12 focus areas around the north and northeast of Thailand and expanded the area of Riceberry cultivation certified under international organic standards (IFOAM) to 5,440 hectares (Vanavichit, 2020). The cultivation of Riceberry in Thailand has grown to a maximum of 6,064 hectares in cropping year 2015/16, after which it gradually dropped due to restrictions in organic production and market conditions. The Riceberry seed and organic production techniques were continuously transferred to small community enterprises. Meanwhile, Riceberry has been endorsed under a plant variety protection law since 2017 and licensed for controlled seed trade in Thailand under registration numbers 88/2560 and 88/2561.

The programme supervised by Dr. Apichart first positioned Riceberry in the market for organic products and set out to meet several quality standards for organic rice production and good manufacturing practices (GMP) of rice milling, packaging and food processing according to hazard analysis and clinical control points (HACCP) (Malumpong et al., 2010). The trademark has been registered both in Thailand and internationally under the department of Intellectual Properties since 2011. While these are owned by Thai public institutes, they can be licensed for use in the global market (Vanavichit, 2020). Recognising the introduction of Riceberry as heathy and organic rice, there are approximately 3,200 hectares of Riceberry registered to a variety of organic certification programmes including Organic Agriculture Certification Thailand, IFOAM, EU, COR and USDA (Vanavichit, 2020). Over time, the nutritional benefit of Riceberry became widely recognised among Thai consumers and later also in global market. In the domestic rice market, Riceberry has the largest market share for black-coloured rice at about 20,000 tonnes/year. On the global market, Riceberry has remained a small niche product (Napasinthuwong, 2020). The potential of Riceberry in food processing is reflected in the fact that there are more than 18 food

and drink products from Riceberry that have obtained patents and have been launched to market in Thailand (Vanavichit, 2020).

The timeline presented in Figure 5.1 provides a summary of documented activities and interventions related to the Riceberry research programme as derived from official documentation. The figure indicates that we can distinguish three phases according to the main outputs of each phase. The first phase of the research programme led by Dr. Apichart aimed at breeding a new rice variety with improved nutritional value. The second phase led by Dr. Ratchanee was oriented to developing primary food products based on Riceberry such as rice bran and instant food. Finally, a research and development (R&D) project for the standardisation of Riceberry and its primary products supervised by Dr. Apichart can be considered as Phase 3 (Malumpong et al., 2010).

Table 5.2 gives a summary overview of the inputs, outputs, outcomes and impacts of the Riceberry programme as described in a recent impact assessment study which is largely based on official documentation (Praneetvatakul et al., 2018). In the next section, we provide a more detailed reconstruction of the impact pathway for each of the phases distinguished in Figure 5.3, using our analytical framework and combining different data sources, including in-depth interviews with key actors.

Table 5.2 Inputs, outputs, outcomes and impact of the Riceberry programme as represented in a conventional impact assessment

Items	Number
Inputs	
- Research budget (2004-2012)	0.85 million USD (28.5 million Baht)
- No. of researchers in research programme	46
Outputs	
- New rice variety, Riceberry	

Table 5.2 (continue)

Items	Number
Outcomes	
- Scientific publications in international journals	12
- Non-scientific publications and media appearance	Approx. 18,700 times
- Plant Variety Protection in Thailand No. 0423/2560	1
- Permit of controlled seeds for trade in Thailand for Riceberry seed No. 88/2560 and 88/2561	2
Impacts	
- Economic impact at 2018 (Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR))	NPV 18 million USD (599 million Baht) BCR 16.38 IRR 50%

Source: Praneetvatakul et al., 2018

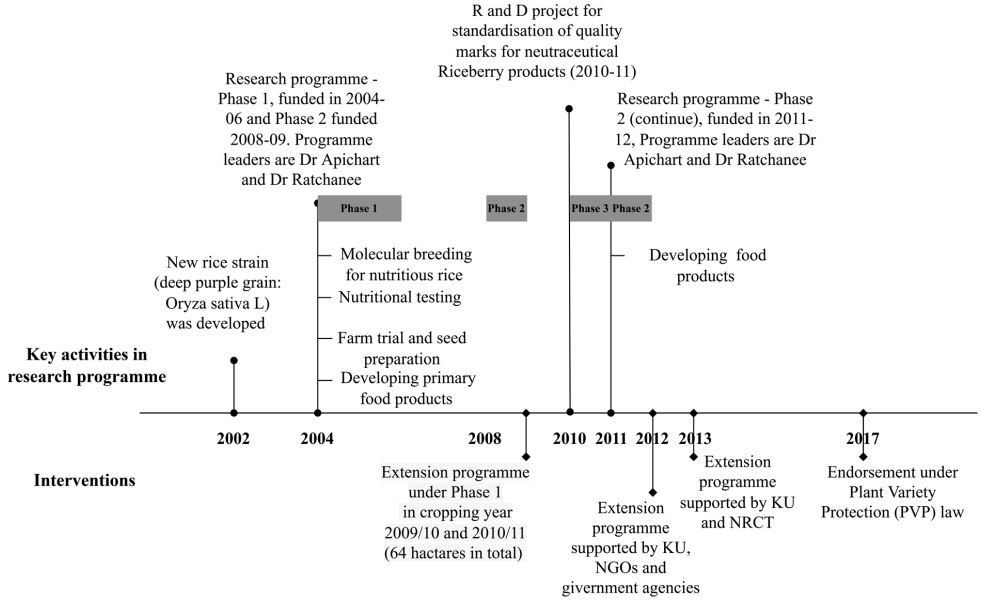

Figure 5.2 Timeline diagram of key formal activities of the Riceberry research programme and related interventions.

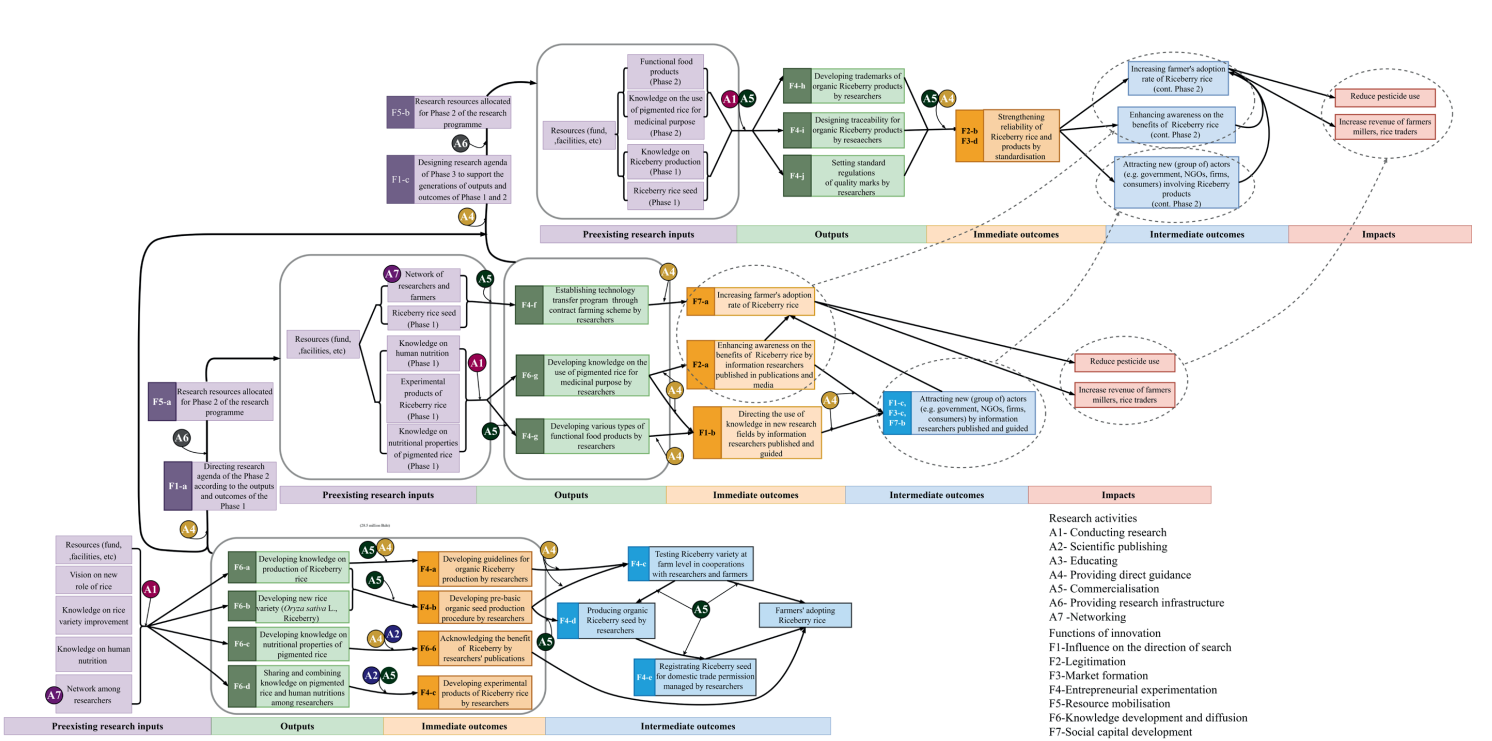

Figure 5.3 Impact pathway of the Riceberry research programme

5.4.2. *The activities performed by research programme leaders in the impact-generating process*

In this section, we describe in greater detail how activities performed by researchers and programme leaders link to the Riceberry impact-generating process. For each phase, the impact pathway was depicted, presenting the characteristics and the main resources mobilised for research (or research inputs), the resulting products (outputs) and the immediate and intermediate outcomes and impacts. As discussed in our analytical framework, we aim to capture the role of researchers along the entire pathway by specifying their activities (A1-A7) at the interfaces (i.e. the arrows) between inputs, outputs, outcomes and impacts. At the same time, we characterise the various 'inputs', 'outputs' and 'outcomes' in terms of the functions that they fulfil in building the innovation system (F1-F7).

The first phase: Development experimentation and initiation of the use of Riceberry

The first phase of the research programme focussed on knowledge creation oriented to the development of the new high nutrition rice variety, *Oryza sativa L* (common name: Riceberry) as the main output. Beyond the creation of knowledge-based outputs, we see that researchers broaden their activities from conducting research and providing research infrastructure towards activities in the sphere of commercialisation and offering guidance for practice, resulting in several immediate and intermediate outcomes that serve to stimulate adoption and utilisation of the new rice variety. Early in the innovation process, researchers shared their interest in developing high nutrition rice variety that led to joint agenda-setting. A network of plant breeding and nutrition researchers was formed to organise interdisciplinary research under the supervision and guidance of the programme leader. Conducting research together enabled synergies such as co-production and utilisation of knowledge. Knowledge was exchanged and shared among the researchers who had different expertise. The results from nutrition research provided guidance and advice for rice breeding researchers relevant to ensuring nutritional value, fragrance and the taste of rice. The research outputs, including the new rice variety, as well as new knowledge on the relation between genetics and nutritional properties, were disseminated to farmers by

the plant breeding researchers. The commercialisation activities were carried out in various ways by researchers. For example, researchers developed new procedures and guidelines for Riceberry production that were subsequently demonstrated and tested in farm experimentation activities that were simultaneously intended to stimulate the adoption of the Riceberry at the farm level. In addition, the programme leader played significant roles in mobilising support for technology dissemination at higher government levels and, as a necessary condition for this, in obtaining the permission for domestic trade in Riceberry seed. Moreover, the functional food products from Riceberry were developed and experimented with as an integral part of this phase. The information on Riceberry and its benefit was not only disseminated to farmers and scientific communities but also to rice consumers by publishing in both scientific and non-scientific publications. This dissemination resulted in public acknowledgement of Riceberry's benefits.

As is summarised in Figure 5.4, researchers performed a wide range of activities in the first phase of the Riceberry programme, and many of these eventually supported functions related to knowledge development and diffusion. Other functions that are supported (e.g. entrepreneurial experimentation and direction of the search) also tend to be closely linked with knowledge creation. Interestingly, knowledge development involved a wide range of interconnected topics and spheres of action, including breeding and genetics, nutrition, food processing, seed multiplication and agricultural extension. This also involved offering guidance to numerous actors and the building of trust and social capital in a network relevant to achieving impact. At this stage, the impact at the farm or food system level is still embryonic.

Phase 1

Fucntions / Activities	F1: Influence on the direction of search	F2: Legitimation	F3: Market formation	F4: Entrepreneurial experimentation	F5: Resource mobilisation	F6: Knowledge development and diffusion	F7: Social capital development
A1: Conducting research		■				■	
A2: Scientific publishing						■	
A3: Educating							
A4: Providing explicit guidance	■			■		■	■
A5: Commercialisation				■		■	
A6: Providing research infrastructure					■		
A7: Networking						■	

Figure 5.4 Influence of research programme leader activities on functions in the first phase of the research programme

The second phase: Building legitimacy and nursing a market for Riceberry

The second phase of the research programme aimed at a) developing various types of functional food such as rice bran products, rice flour and beverages for diabetes and b) increasing adoption of Riceberry in different areas. The research outputs and outcomes of the first phase were continuously used as input for the second phase of the research programme. In terms of research activity, we see continued research and development (R&D) on the use of Riceberry for the production of and various types of functional foods. We also see that researchers continue activities in the sphere of commercialisation, the provision of guidance and network building, mostly oriented to outcomes that strengthen awareness, support and adoption of Riceberry.

The nutrition researchers conducted several experiments that served to generate knowledge on the use of Riceberry and other pigmented rice varieties for medical purposes and various functional foods. The information on Riceberry's nutritional benefits was increasingly disseminated, especially via non-scientific publications and very high levels of media exposure (see Table 5.2). The seed production procedures

developed in Phase 1 were transferred through informal networks between farmers, community enterprises and researchers. Through the fostering of linkages with extension programmes in the cropping seasons 2009/10 and 20010/11, the area of cultivation expanded to 64 hectares. To further support the adoption of the technology, the researchers supported the establishment of a contract farming scheme for farmers and community enterprises. The research programme leader also enrolled additional firms, NGOs, government agencies who were interested in Riceberry, and supported these in setting up technology transfer programmes through the provision of information and guidance related to Riceberry. As a result, the adoption rate of Riceberry increased, which led to intermediate outcomes such as reducing pesticide use and increasing revenue for farmers. Compared to Phase 1, it is interesting to note that many of the researcher activities during Phase 2 were informal in the sense that they were not officially planned, programmed or funded as part of the Riceberry programme.

As is summarised in Figure 5.5, the researcher activities gravitated even further to providing guidance to others, and fulfilling the function of knowledge development and diffusion became less prominent. Instead, we see that the outcomes serve to perform functions like legitimation, entrepreneurial experimentation and market development, which are all important in creating enabling conditions for uptake. The activities 'providing explicit guidance' and the resulting public media attention served to build legitimacy, trust and recognition of Riceberry among rice consumers, which in turn supported market formation and direction of the search for new actors.

Phase 2

Fucntions / Activities	F1: Influence on the direction of search	F2: Legitimation	F3: Market formation	F4: Entrepreneurial experimentation	F5: Resource mobilisation	F6: Knowledge development and diffusion	F7: Social capital development
A1: Conducting research		■		■		■	
A2: Scientific publishing							
A3: Educating							
A4: Providing explicit guidance	■	■	■				■
A5: Commercialisation				■		■	
A6: Providing research infrastructure					■		
A7: Networking				■			

Figure 5.5 Influence of the research programme leader's activities on functions in the second phase of the research programme

The third phase: Strengthening legitimacy and market access for Riceberry

In the final phase of research programme, a central aim was to strengthen quality management for Riceberry and its products. Standards for organic agriculture were leading in this regard, since the Riceberry technology was positioned as organic rice and was mostly transferred to farmers and community enterprises under an organic production scheme (Vanavichit, 2020).

In this phase, research activities were conducted mainly to create and test the technology quality management process (see Figure 5.6). In the impact pathway, the research results have been applied to instruct farmers and firms on quality management of Riceberry and the products, namely rice bran oil and oil-free bran. Commercialisation and guidance activities focussed on enhancing the quality and reliability of Riceberry and its products. The main research outputs consisted of several quality trademarks and regulations for quality management for farming, packaging and secondary products (rice bran oil and oil-free bran) (Malumpong et al., 2010). The

trademarks have been registered successfully both in Thailand and internationally under the department of Intellectual Properties since 2011, and they can be licensed for use in the global market (Vanavichit, 2020). Assumedly, these trademarks and standards served indeed to strengthen the reputation of Riceberry and products and reinforced the continued efforts to stimulate the uptake of Riceberry with the help of a growing network of partners and technology transfer programmes (see Phase 2).

As is summarised in Table 5.5, the activities of researchers and programme leaders narrowed further in Phase 3 and concentrated on commercialisation and provision guidance. The activities mainly supported the functions of market formation around Riceberry and legitimation of its position as an organic quality product.

Phase 3

Fucntions / Activities	F1: Influence on the direction of search	F2: Legitimation	F3: Market formation	F4: Entreprenеurial experimentation	F5: Resource mobilisation	F6: Knowledge development and diffusion	F7: Social capital development
A1: Conducting research							
A2: Scientific publishing							
A3: Educating							
A4: Providing explicit guidance							
A5: Commercialisation							
A6: Providing research infrastructure							
A7: Networking							

Figure 5.6 Influence of the research programme leader's activities on functions in the third phase of the research programme

5.5 Analysis and discussions

We have combined a functional approach with impact pathway analysis to develop a detailed and systematic insight into the role of Riceberry research programme leaders in working towards the uptake of their innovation over a long period that included different programme phases. Below, we reflect upon the results with regard to both the role of researchers in system-building and on the value of integrating the two approaches for understanding and supporting impact generation.

5.5.1. Researchers perform a variety of intermediation roles along the impact pathways

We have observed that researchers performed various activities along the three interconnected impact pathways in an iterative, complex and dynamic innovation trajectory. Interestingly, classical research activities such as doing research and producing scientific publications actually play a rather modest role; over time, the research activity becomes mainly linked to entrepreneurial experimentation. The three summary tables in Section 4 indicate that the programme leaders activities become more narrow over time, and increasing gravitate towards commercialisation and the provision guidance to a variety of societal actors, thereby serving innovation systems functions that foster enabling conditions for the uptake of Riceberry such as legitimation, entrepreneurial experimentation and market development. It can be noted that a particular type of activity can contribute to the realisation of several innovation system functions at the same time, and that specific functions can be supported through a variety of activities.

The case study exemplified that researchers, and especially the programme leader, undertook and acted in the sphere of market development and supporting socioeconomic transformation processes through commercialisation activities, as also deemed relevant by for example Molas-Gallart et al. (2002) and Matt et al. (2015). This included efforts to create new products and processes, as well as supporting and participating in firms, community enterprises, seed distribution programmes and farmer groups. As part of this, considerable attention was paid to issues pertaining to

intellectual property, licensing and certification as enablers for putting Riceberry into commercial use (OECD, 2013).

Activities in the sphere of offering guidance to policy actors and the general public frequently had a clear communicative dimension, and researchers invested considerably in developing non-scientific publications and in generating media attention. The latter is actually less well covered by the activities suggested in Table 5.1 which were derived from Bergek et al. (2008) Jacobsson and Perez Vico (2010) and Perez Vico (2014). Given this finding and the general significance of dynamics in (social) media landscapes in society, it may be worthwhile to distinguish such activities more clearly and visibly in future analysis.

We can conclude that Riceberry researchers, and especially the programme leader, played a key role in supporting the uptake of Riceberry as a step towards achieving impacts such as income generation and the improvement of human and environmental health. In the literature, this has also been referred to in terms of playing intermediation roles (Joly et al., 2015; Klerkx & Aarts, 2013). Recognising the significance of the intermediary roles that agricultural researchers may play can help to overcome limitations such as weak institutional arrangement, poor availability of specialised human resources (Faure et al., 2018) and a lack of incentives for innovation (Gijsbers and Tulder, 2011) that are frequently found in agricultural innovation systems of developing countries.

5.5.2. *The significance of informal activities as an adaptive mechanism in innovation system-building*

As indicated in Section 2, there are a number of studies on research impact that rely on the analysis of officially documented and contracted activities (Olmos-Peñuela et al., 2014).

Our case study of the Riceberry research programme suggests that both formally documented and more informal activities play vital roles in developing multiple innovation system functions. According to the formal programme documents, the main research activities included conducting research, knowledge and technology

transfer and commercialisation activities, which took place along a timeline as represented in Figure 5.1. Using such documents for an impact pathway analysis, one would arrive at a description of inputs, outputs, outcomes and impacts as depicted in Table 5.2. In our case study, we combined document analysis with in-depth interviewing of key informants, and this has resulted in a much more detailed and sophisticated timeline and impact pathway that includes many activities and achievements that are not mentioned, announced or explained in the formal research documents (see Figure 5.2). In particular, we see that many of the activities in the sphere of providing guidance via communication, networking and consultation took place in a manner that was not planned in advance. However, such complementary activities seem to have contributed considerably to achieving functions and process outcomes related to 'influencing direction of the search', 'legitimacy', 'entrepreneurial experiment' and 'social capital development' (see Figure 5.2). Interviews with programme leaders suggest that these informal activities tend to occur when there are unforeseen developments and dynamics in the context of interactions with stakeholders that are geared towards creating and enabling environment to achieve impact. Thus, we see that impact pathways cannot be planned in detail, and that improvisation and adaptation can be important. In the complex and dynamic process of impact generation, informal activities arguably reflect adaptive management capacities at the micro level through which programme leaders contribute to socio-technical change (see also Klerkx et al., 2010).

5.5.3. Complementary innovations and system-building processes to enable the development and diffusion of Riceberry.

Our approach to combining a functional approach with impact pathway analysis has enabled us to demonstrate how programme leaders can be seen as bottom-up system builders and engage in a variety of activities that help realise important functions of technological innovation systems (see Sections 4 and 5.1). While the idea of technological innovation systems (Hekkert & Negro, 2009) takes a technological innovation (in our case the Riceberry variety) as the starting point, it is interesting to note that many of the activities of the programme leader are geared towards

developing appropriate social-organisational conditions for the uptake of the technology. These conditions included the establishment of novel organisational arrangements for seed production and distribution, contract farming schemes, quality control and certification systems, community enterprises and extension programmes. While we have so far analysed and framed such social-organisational arrangements in terms of fulfilling functions that create an enabling environment for the uptake of the Riceberry technology, several of these functions could also be regarded as (non-technological) innovations in their own right. This finding is in line with recent perspectives on agricultural innovation and scaling, which emphasise the importance of aligning different innovations in a package or bundle (Sartas et al., 2020; Barret et al., 2020). From this perspective, we could see the Riceberry variety as a core innovation that requires a range of complementary innovations in order to go to scale. These innovations include other technological innovations (e.g. processing techniques for the creation of high-quality Riceberry food products) as well as social-organisational or institutional innovations (e.g. the types of novel social-organisational arrangements mentioned above). According to Sartas et al. (2020), components in a package of interdependent innovations can each have a different level of maturity or readiness (ranging from an idea or hypothesis to something that has been proven to function in a non-protected environment), as well as varying degrees of societal support in a specific context, and it is suggested that innovation components with the lowest maturity and support can be considered as 'bottleneck innovations'. From this perspective, we can interpret the observed impact pathway as a trajectory in which research programme leaders take action to tackle the most salient bottleneck innovations at a particular point in time. These bottlenecks then change over time, which is consistent with the observation that the focus of activities evolves throughout the three phases of the programme. Interviews with programme leaders suggest that the idea of 'navigating evolving bottlenecks over time' resonates well with their own interpretation of their activities.

5.6 Conclusions

In order to develop a detailed insight into the roles that research programme leaders may play in contributing to societal impact, we combined an analysis of how research activities contribute to fostering innovation system functions (e.g. Jacobsson and Perez Vico, 2010; Perez Vico and Jacobsson, 2012; Jacobsson et al., 2014) with impact pathway analysis (Douthwaite et al., 2003; Springer-Heinze et al., 2003). Our analysis and experience suggest that the two approaches to studying impact generation indeed complement each other usefully. The functional approach clarifies how the activities of research programme leaders contribute to the realisation of overall innovation system functions that are relevant to ensuring the uptake of -in our case- the Riceberry variety. The use of impact pathway analysis across three overlapping programme phases has been useful to clarifying how activities and functions realise with the help of these shifts over a long time. At the start, we see a relatively wide range of different activities, of which many are related to functions linked to knowledge creation. Over time, we see that activities gravitate slowly towards commercialisation and offering guidance to others (whereby media performances play an important role) and that innovation systems functions supported shift towards legitimation and market development. In doing so, the Riceberry research programme leaders took on a remarkable degree of responsibility for building the innovation system and creating an enabling environment for the use of Riceberry. This finding on the programme leaders' responsibility/roles for building the innovation system and creating an enabling environment for their technological innovation may relate to the fact that they operated in a developing country where institutional support structures for innovation system development may be relatively weak (Gijsbers and van Tulder, 2010; Bryerlee, 1998). The reconstruction of the impact pathway with the help of in-depth interviews also usefully revealed the importance of informal activities that are not officially planned, programmed or funded in system-building, and this reconstruction also made more visible that programme leaders' de facto work on a package of interdependent technical, organisational and institutional innovations rather than on a single innovation. The combined functional and impact pathway analysis also

suggests that system-building is an iterative and adaptive process in which research programme leaders navigate and come to grips with emerging challenges and constraints. Explicating and placing the researcher activities as distinguished in the functional approach at the interfaces between the inputs, outputs, outcomes and impacts that together form the impact pathway has contributed to this insight. This mode of analysis reveals more clearly that researchers do not only take action at the early stages of impact generation (e.g. when research inputs are transformed into research outputs) but can also usefully facilitate and support later stages where outcomes and impacts are being realised. In all, we feel that studying the generation of societal impact may benefit from combining a functional perspective with impact pathway analysis. On the basis of this first exploration, the approach can be further developed and refined, for example by distinguishing a broader set of activities and by developing further methodological guidance for ex post analysis of impact generation trajectories. Exploring the potential of the approach for the ex ante formulation of impact strategies would also be an interesting next step.

Appendix

Data sources: Project reports and publications on Riceberry research programme

This study reports the results of analyses of data from several sources collected in in-depth interviews, project reports and scientific and non-scientific publications on Riceberry. This appendix collected the project reports and publications directly related to the Riceberry research programme.

Project reports

- *Final Reports of Riceberry research program*

Vanavichit A., Sinchaipanich, P., Wongpornchai, S, Kongkachuichai, R. Sirijakkrawan, P., Songjitrasomboon, S., Leardkamolkarn, V. (2005). *Integrated biotechnology in developing rice strains for high value-added and nutritional enrichment – Phase 1.* (unpublished report) in Thai. National Research Council of Thailand. Bangkok.

Vanavichit A., Sinchaipanich, P., Wongpornchai, S, Kongkachuichai, R. Sirijakkrawan, P., Songjitrasomboon, S., Leardkamolkarn, V. (2010). *Integrated biotechnology in developing rice strains for high value-added and nutritional enrichment – Phase 2.* (unpublished report) in Thai. National Research Council of Thailand. Bangkok.

Malumpong, C., Sukheewong, A., Ruengpayak, S., Chakebut, D., Puengbumrung, S., Unsuwan, P., Khunawuttinun, M., Hoimala, S., Vanavichit, A. (2010). Thanya Osod: Standardization of Quality Mark for Neutraceutical Rice Products. (unpublished report) in Thai. National Research Council of Thailand. Bangkok.

- *Reports of Economic impact of Riceberry research program*

Praneetvatakul, S, P. Pananurak, K Vichitsrikamol, A Sirijinda. (2018). *Study on the Impact Assessment of Rice Breeding Research Projects under National Science and Technology Development Agency (NSTDA)* (unpublished report) in Thai. Applied Economic Center. Kasetsart University.

Scientific Publications

Leardkamolkarn, V., Thongthep, W., Suttiarporn, P., Kongkachuichai, R., Wongpornchai, S. & Vanavichit, A. (2011). Chemopreventive properties of the bran extracted from newly-developed Thai rice: The Riceberry. *Food Chemistry*, 125(3), 978-985.

Vanavichit A. (2020). Riceberry Thailand's antioxidant-packed nutraceutical and super food. *Research Outreach* (112). Retrieve from https://researchoutreach.org/wp-content/uploads/2020/02/Apichart-Vanavichit.pdf

Chapter 5

Chapter 6

General discussions

6.1. Introduction

This dissertation focuses on how an agricultural research system realises certain functions and contributes to research impact-generating process, using the case study of Thailand's rice sector. The main objective of this dissertation therefore was to understand the processes through which the rice research system in Thailand contributes to the generation of societal impact.

The impact-generating process in the rice research system in Thailand is studied from an innovation systems perspective. To do so, the following main research question was set: How does the rice research system perform as a component of an agricultural innovation system (AIS) to contribute to achieve societal impacts of rice research? The main assumption of the dissertation is that the contributions of agricultural research in the impact-generating process are on different levels of aggregation in the agricultural research system (ARS), including the overall system level, the level of research programmes and the level of individual researchers. This dissertation, therefore, attempts to unravel the contributions of the rice research system in Thailand on the impact-generating process through a) determining the structural and functional development of the rice research system, b) investigating the perspectives of individual researchers on impact orientation and c) analysing the roles of individual researchers in enhancing the impacts of rice research at the programme level. In order to answer the main research question, four sub-research questions were investigated through different case studies: a) What are the key components, their linkages and relations of the innovation system for Thailand's rice sector? b) How has the rice research system in Thailand developed over time in terms of its structure, management, and influence on the functions of the research system? c) How do individual researchers engage in impact-oriented activities and what are the determinants for the engagement of the impact-oriented activities? and d) What are the roles of individual researchers as project/programme leaders in enhancing the impacts of rice research?

In this final chapter, the findings from the different case studies elaborated in Chapters 2 through 5 will be summarised. Furthermore, I will discuss cross-cutting issues across chapters, with a focus on the contribution of agricultural research to impact-generating processes at different levels of aggregation. From this reflection theoretical implications are drawn. The chapter closes with recommendations for policy and future research emerging from the insights from the chapters and the cross-cutting discussion of these.

6.2. A summary of the research findings

The main findings of each empirical chapter associated the sub-research questions are presented here, followed by the discussions on the main findings, scientific and conceptual reflections and recommendations of this dissertation.

Overview of the innovation system in the rice sector

In Chapter 2 of the thesis, I reviewed the literature on actors, technologies and policies related to rice in Thailand, and how they interact in shaping the innovation system in the rice sector. Within the innovation system of the rice sector, the key features, namely, market demand, the business domain, the research domain, the intermediate organisations and related policies and regulations, are presented. The rice sector in Thailand has developed with government support since 1950s. The outstanding position of Thai rice in the global market results from an intensive knowledge flow among the different domains based on investing in public research and extension. However, the interactions between the business and research domains are still limited. The knowledge flow within the rice sector is found to be rather linear. It is important to stimulate knowledge flows and interaction among the different domains. The roles of the intermediate organisation and the conditions to stimulate collaboration between different domains should be emphasised.

The development of the rice research system in Thailand

Taking the case of the rice research system in Thailand, Chapter 3 shows the development of the Thai rice research system, which is analysed considering its structure and functions. This chapter shows chronologically that the development of Thai rice research reflects a shift in technological paradigms focusing on rice production, evolving from a Green Revolution paradigm to a biotechnology paradigm and eventually an agri-food value chain paradigm. Shifting to the agri-food value chain paradigm allowed moving away from a linear perspective on research and innovation and bringing in a wider range of actors to provide input to research and innovation processes and support the wider uptake of research-based knowledge.

Nonetheless, this chapter has demonstrated that the development in terms of management of the rice research system seems not to be inclusive. The rice research system has a strong centralised top-down management that results in the slow development of the research system functions relating to research planning and M&E. Decentralisation of public sector decision-making and resource allocation can be key factors in making rice research more efficient and responsive to research demands. The shifts in the dominant technological paradigms allow new research areas and new actors to engage in rice research. There have been collaborations both among the public research organisations and universities and between public research and the private sector, including farmers. However, despite this changing paradigm, in practice, the experience of the rice research system in Thailand is similar to that in other developing countries where the ARS structure is dominantly formed and developed by a closed group of public research organisations (Byerlee, 1998; Gijsbers and Van Tulder, 2011). Interaction aimed at developing and diffusing knowledge in collaboration with the private sector remains low.

The individual perspectives of rice researchers in Thailand in engaging with impact orientation

Chapter 4 shows that it is possible to identify three different groups of researchers based on the activities related to the impact orientation of their research. The impact-oriented activities refer to knowledge exchange and dissemination in various forms

(e.g. the development of techniques, approaches and policy implications) and the involvement of stakeholders in research. Results of econometric analyses show that among the three identified groups of researchers, researchers in Group A (34% of all respondents) tend to perform at the same time various activities related to the three groups of impact-oriented activities identified, namely engaging stakeholders in research, transferring knowledge, and engaging in policy process. Researchers in groups B (37% of all respondents) and C (30% of all respondents) are likely to conduct the three groups of activities at a lower degree compared to Group A. Both Groups B and C seem to rather focus on performing one group of activities, respectively involving stakeholders in their research and transferring knowledge. The factors including work experience, types of organisation researchers work for, attitudes towards impact-oriented activities, and perceptions of supportive conditions in organisations were identified as determinants of the different degrees of engagement in impact orientation practices of researchers. Overall, the results of this chapter provide insights on different attitudes towards impact orientation and perceptions on organisational conditions among researchers with different degree of engagement in impact-oriented activities.

The roles of research programme leaders in enhancing the impact of the Riceberry research programme

In Chapter 5, the roles of research programme leaders play in contributing to societal impact are explored by the combination of the function of technological innovation system (TIS) approach (Vico and Jacobsson, 2012) and impact pathway analysis (Douthwaite et al., 2003; Springer-Heinze et al., 2003). The activities of research programme leaders contribute to the realisation of overall innovation system functions that are relevant to ensuring the uptake of, in our case, the Riceberry variety across three overlapping programme phases. The Riceberry research programme leaders took on a remarkable degree of responsibility for building the innovation system and creating an enabling environment for the use of Riceberry. We see a relatively wide range of different activities (such as conducting research, providing explicit guidance, commercialisation, networking), of which many are related to functions linked to

knowledge creation, legitimation and market development. Early in the trajectory, we see a relatively wide range of different activities, of which many are related to functions linked to knowledge creation. Over time, we see that activities gravitate slowly towards commercialisation and offering guidance to others, and that the innovation systems functions supported shift towards legitimation and market development. The results also reveal the importance of informal activities that are not officially planned, programmed or funded in system-building, and make more visible that programme leaders' de facto work on a package of interdependent technical, organisational and institutional innovations rather than on a single innovation. The researchers do not only take action at the early stages of impact generation (e.g. when research inputs are transformed into research outputs), but also usefully facilitate and support later stages where outcomes and impacts are being realised. Combining the functions of TIS approach with impact pathway analysis in Chapter 5 enables the development of a detailed and systematic insight into the role of programme leaders as system builders who engage in a variety of activities and work towards the uptake of their innovation over a long period that included different programme phases. The combined functional and impact pathway analysis also suggest that system-building is an iterative and adaptive process in which research programme leaders navigate and come to grips with emerging challenges and constraints.

The summary of each chapter in this dissertation and the connection of the four chapters are presented in Figure 6.1. As shown in the figure, the A, B and C arrows represent interlinked between each level within the research system and the innovation system in the Thai rice sector. Arrow A represents the link between individual factors and activities, Arrow B represents the link between activities performed by researchers and functions of TIS and Arrow C represents function of research system in the interrelated levels. In the next section, the connection between the chapters will be discussed.

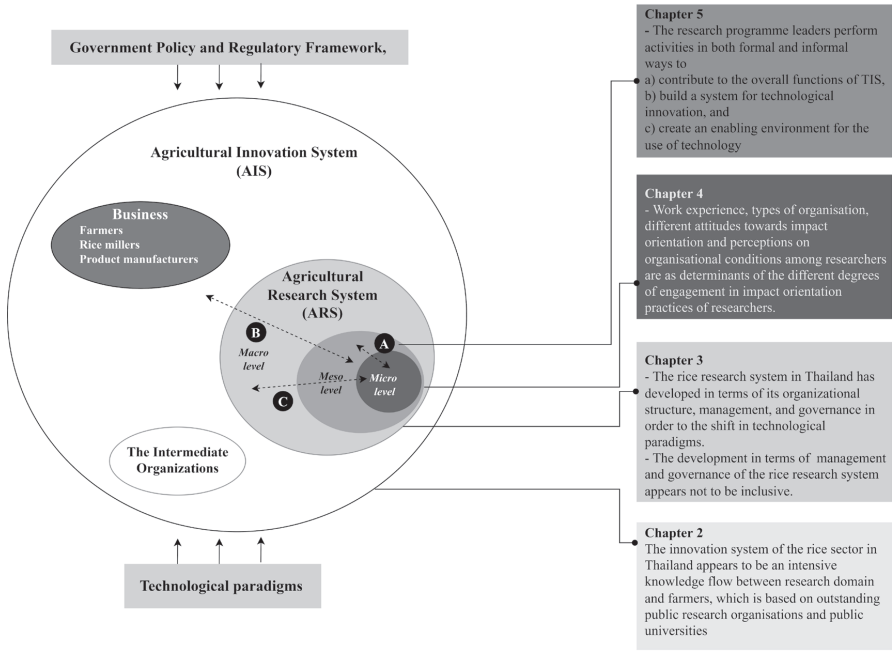

Figure 6.1 The summary of the findings in each chapter and the connections of the chapters.

6.3. Discussions on cross-cutting issues from the dissertation

This dissertation highlights the issues regarding the contributions of agricultural research to the impact-generating process, especially in developing countries that have undergone criticisms regarding poorly functioning institutional mechanisms in agricultural research systems (Gijsbers and Tulder, 2011). In this section, I discuss three cross-cutting themes on a) asynchronous development across the levels of the rice research system, b) complementary contributions of the system and individual levels of the rice research system in Thailand on impact generation and finally c) mismatches regarding the rice research governance system (see Arrow A, B and C in Figure 6.1).

6.3.1. *Asynchronous development across the levels of the rice research system*

The adoption of an agricultural innovation system (AIS) perspective has major implications for agricultural research, in terms of interactive work with stakeholders in setting the agenda of research, knowledge co-production, and an inter-and multi-transdisciplinary approach to tackling complex innovation issues (Röling, 2009; Schut et al., 2014). However, it has been shown that institutional arrangements often do not support a systemic approach to innovation with corresponding broad roles for researchers in support co-innovation (Hall et al., 2001; Klerkx et al., 2017). The findings on the development of the rice research system in Thailand present deeper insights on the co-evolution of technological paradigms and institutional arrangements.

The co-evolution processes relate to the structural and functional development of the rice research system. It is noticeable that the development of the rice research system remains under strong influence of the NARS concept that considers agricultural research as the central domain of agricultural development. The new organisations and new research units that have been continuously established since the 1950s still mainly focus on the supply side of the research system. The structural development is dominantly formed and developed by a closed group of public research organisations. The collaborations in the rice research system tend to be limited among the public research actors and between public research and farmers and the interaction with the private sector in determining research priorities remains low. Consistent with the result from the studies by Hall et al. (2000) and Gijsbers and Van Tulder (2011), the tendency of institutional arrangements in the rice research system in Thailand focus on enhancing the institutional structure within public research (e.g. establishing new research units in public research organisations) rather than to focus on institutional arrangements to enhance the integration of stakeholders into the existing system (Fuglie and Toole, 2014). The main conclusion is that the Thai rice research system has gradually developed in terms of structural characteristics and functions in response to the evolution of technological paradigms. Structural components of the research system have developed in line with functional needs and the functions of the research system (such as agenda-setting, resource allocation, interaction with stakeholders)

influence and reinforce one another but the structural and functional development may not develop in a synchronised fashion.

Unlike the development at the research system level, the individual researchers (see Chapter 4) conduct the activities including involving stakeholders in research, transferring knowledge and involving them in the policy process. This hints at the individual researchers' adoption of AIS by reflecting the characteristics of research approaches that facilitate the interaction between research and actors (e.g. farmers and policymakers) and make agricultural research more grounded in the context of reconciling the supply of scientific information with the actors involved and the wider set of relationships in which research is embedded. Similar to the previous studies, researchers may be involved in activities that contribute to network and coalition formation around specific innovations, described according to their roles as 'system builders' (see Hellsmark & Jacobsson, 2009; Perez Vico, 2014) and 'innovation champions' (Shambu Prasad, 2006; Klerkx et al., 2010). This is in line with the finding of Chapter 5 that the individual researcher perform both conventional (e.g. conducting research, scientific publishing) and unconventional (e.g. providing explicit guidance, commercialisation, networking) research activities to link with a variety of societal actors and create enabling environment to achieve impacts.

6.3.2 Complementary contributions of the system and individual levels of the rice research system in Thailand on impact generations

The contributions of research to impact generation can be described in terms of functional development (see Jacobsson and Vico, 2010; Vico and Jacobsson, 2012; Jacobsson, Vico and Hellsmark, 2014). The functions refer to the key processes of research to develop, diffuse and utilise knowledge. The two functionalist approaches are applied to trace the crucial process of functional development of the research system in Chapter 3 and the technological system in Chapter 5.

The development of the rice research system in Thailand presents the new institutional arrangements focusing on the function directly related to structural development. The function of 'organisational variation and novelty creation', 'locus of control on the

direction of research' and 'diffusion of knowledge within the research system' are well developed through the participation of a wide range of actors and the establishment of new organisational forms in public research. Nonetheless, the development of functions related to priority setting and funding allocation including research assessment 'resource allocation and main funding mode' and 'evaluation procedure' has relatively lagged behind. The way in which these two functions are organised possibly implies the mismatch of demand–supply of the research system. Although the private sector, such as food manufacturers, pay more attention to investment in R&D through collaborative research, the investment in R&D activities in rice research remained low.

The institutional contexts in different levels of the research system are interlinked and reinforce one another in how they enable or constrain research as presented in Klerkx et al. (2017). The study by Faure et al. (2018) suggested that in the context of developing countries that often show weak institutional arrangements, the functions to pursue impact can be fulfilled by the roles and activities performed by individual researchers. The pieces of evidence from both Chapters 3 and Chapter 5 are in accordance with the key conclusion by Faure et al. (2018) that researchers perform different roles focusing on facilitating joint knowledge production and learning with or among actors involved (Schut et al., 2011; Faure et al., 2018), such as lobby and advocacy activities (Basu and Leeuwis, 2012). The finding in Chapter 5 show that researchers perform a variety of functions along the impact pathway in contributing to building a system for a technological innovation via functions to diffuse knowledge and connect the technology to various actors (e.g. farmers, markets, consumers). This emphasises the significance of the roles performed by agricultural researchers in helping to overcome limitations such as weak institutional arrangement (Faure et al., 2018; Gijsbers and Tulder, 2011). This finding adds perspectives on the additional roles of agricultural researchers to pursue impacts in the context of particular conditions and settings in the sector and country levels.

6.3.3 *Mismatches regarding the rice research governance system*

Chapter 5 reveals that individual researchers and programme leaders take responsibility for the entire impact pathway and orient their activities not only to realising research outputs but also to fostering immediate and intermediate outcomes. The findings from the case study of Riceberry research programme suggest indeed that such activities can be effective, and it is clearly important from an economic and development perspective that researchers give time and efforts in impact-oriented activities.

The findings in Chapter 4 suggest that a considerable proportion of researchers is interested to work along similar lines and contribute to the effective use and embedding of knowledge and technology in society. However, when looking at the way research is currently funded and evaluated in the Thai rice research system (see Chapter 3), we see that these kinds of activities are not systematically considered. Formats for research proposals invite researchers to justify and expand on the relation between 'research inputs' and 'research outputs' and provide little space for including activities and explanations on how 'outcomes' and 'impacts' may be realised. Similarly, the criteria and formats for evaluating such proposals are also focussed on assessing proposals in terms of the quality of the relation between research inputs and outputs. In addition, the challenge for evaluation procedure which relies on the peer review system is that peer review is usually in the traditional view tending to support mainstream, hypothesis-driven research. Building research projects relevant to policy and practice in agriculture requires understanding on the shift of the way to think, plan and conduct research from the discovery of scientific information to pursue impact for both policy and practice. This means that rice researchers who write proposals are hardly encouraged to think in advance about and articulate strategies that enhance the chances that research findings are taken up in society. This in sharp contrast to other research systems e.g. CIRAD, the CGIAR, or the Dutch national science agenda where researchers are requested to formulate and underpin an ex ante 'theory of change' or 'impact pathway' as part of the proposal development and assessment process (e.g. Blundo et al., 2018; De Graaf et al., 2017).

Another observation is rice research in Thailand tends to be of a natural science or technical nature, as presented in Chapter 3, even though it frequently happens that bottlenecks to achieving impact reside in the socioeconomic domain (see e.g. Schut et al., 2016; Kilelu et al., 2013; Sartas et al.2020, and Chapter 5). Apparently, there are currently few incentives or opportunities for interdisciplinary collaboration in the way in which the rice research system is currently organised. This observation infers that the selection of research proposal tends to focus on scientific benefits of research.

Finally, the limited attention to impact generation that we observed in the stage of writing and granting research proposals can also be recognised in the stage of ex post evaluation of rice research projects and research institutes. The rice research system in Thailand presents classical evaluation criteria such as the quantity and quality of research outputs tend dominate the evaluation formats and procedure, while the process to achieve 'outcomes' and 'impacts' of research receives less attention (Rajeswari, 1995; Hall et al., 2003).

In all, we see that even though a considerable proportion of researchers has positive attitudes towards activities that are oriented towards generating impact, this is not structurally supported and facilitated by the way in which rice research is currently funded, evaluated and governed. This is likely to negatively affect the contribution of the rice research system as a whole to agricultural development in Thailand.

6.4. Policy and practical implications for science technology and innovation in agriculture

As demonstrated in the empirical chapters, this dissertation highlights the impact-generating process of an agricultural research system at the three levels of an agricultural research system considered: macro-level of research system; micro-level of individual researchers; and meso-level of research project/programme. The contributions of the research system to the impact-generating process are seen as contributions to the key processes of developing, diffusing and using knowledge and technology. The reflections on challenges the rice research system in Thailand is facing

can apply to agricultural research systems in other developing countries. The rice research system in Thailand has shifted in the dominant techno-institutional paradigm, from the Green Revolution to the agri-food value chain that allows new research areas and new actors to engage in interdisciplinary areas of rice research as shown in Chapter 2 and Chapter 3. At the policy and strategic levels, this requires National research funding agencies to ensure that research plans are able to respond to agricultural value chain plans and innovation systems approaches. The new management models for research planning and management consist of mixed portfolio of projects with internal and external funding, funding of interdisciplinary areas that reflect national priorities, use of competitive mechanisms for project selection, participation to a greater extent by different actors from the national agricultural innovation systems in prospecting, prioritisation and definition of research themes as shown in the cases of public agricultural research organisations, e.g. the US Department of Agriculture's Agricultural Research Service (ARS), the Research Branch of Agriculture & Agri-Food Canada (AAFC), the Brazilian Agricultural Research Corporation (Embrapa) and Uruguay's National Agricultural Research Institute (INIA) (Bin et al., 2013; OECD, 2003). In addition, the use of Impact Pathway approach and Theory of Change approach can help public agricultural research organisations and funding agencies to strengthen the planning, implementation and evaluation of impact strategies for research projects.

Considering the role of agricultural research as a component of an AIS, the science policymakers, funding agencies, and research organisations should facilitate the impact-generating process and develop implementations to better disseminate knowledge and new technologies to the broader stakeholders in the AIS. The organisational structure, inter-organisational linkages, and efficient management of the organisations are crucial for the development of an agricultural research system (as discussed in Chapter 4). As shown in Chapter 3, however, the institutional arrangements in the agricultural research system should put weight on improving management and governance for research planning, resource allocation, and monitoring and evaluation system. The public research actors should work together

with a wider range of stakeholders more effectively. The centralisation and compartmentalisation within and between public sector actors in the agricultural research system should be reduced. In addition, new institutional arrangements for research planning, resource allocation, and monitoring and evaluation system such as strategic funding schemes, should be implemented to serve collaborative research, including technology transfer practices; policies with the aim of commercialising and diffusing the knowledge and technologies are required to improve rice research more efficient and responsive to research demands. In addition, the incentives and the supportive conditions should be implemented at the strategic and organisational level to encourage the collaboration between researchers and other actors in agricultural innovation system (Chapter 4).

Increased understanding of the contribution of agricultural research in impact generation allows researchers, research organisations, and funding agencies to address their roles and work together to achieve the impact of agricultural research. This dissertation demonstrates how the system for technological innovation is built through a set of key innovation and diffusion processes for new technology or functions in Chapter 5. The recommendation for the science policymakers is that they need to add elements of system-building activities to facilitate the research organisations and individual researchers to pursue impact generation of research projects/programmes. Given the system-building process, the science policy-making process should seek for the policy and implementations concerning the alignment of structural development and key process of developing and diffusing knowledge in different levels of research system. The policy and implementations should be designed to facilitate the research organisations and individual researchers to pursue impact generation of research projects/programmes.

The effective interventions aimed at creating an enabling environment for impact generation need to coordinate with change in perceptions, attitudes, and practices (World Bank, 2012). Based on the findings in Chapter 4 and Chapter 5, the crucial measures for organisational learning are a variety of efforts, including enhancing learning process among researchers by designing a training programme to broadening

researchers' skills and provisions on formulating impact pathway (or theory of change). The framework of combining research activities, functions of TIS and impact pathway can be included in the training programme to raise researchers' awareness on their roles in impact-generating processes.

6.5. Limitations of the dissertation and future research

This dissertation attempt to understand impact of an agricultural research system in developing countries by exploring the rice sector in Thailand as a case study. However, a number of questions remain unexplored that can be a subject to further study. Based on Hall et al. (2003), the main features of using the innovation systems concept to consider impact of research are that research approaches and outcomes are related to institutional contexts that are played out in the combination of actors involved in research and the patterns of their relationships. Innovation capacity is the combination of function of the actors involved, their skills in bringing to partnerships, and the institutional contexts. This study examines the given features occurred in the aggregation of different levels of the rice research system in Thailand. However, this dissertation put the weight on the actors and institutional context in the rice research system. The functions, skills and institutional contexts of the other components in the innovation system in the Thai rice sector, such as business domain and intermediaries (see Chapter 2), that could influence the operation of the rice research system, have received little attention in this dissertation.

The rice research in Thailand has been seen as public good with the emphasis being on the role of research as a source of knowledge and technologies to tackle problem at the primary phase of rice production. The rice research in Thailand is in fact almost exclusively conducted by the public sector. In Thailand, private companies such as Pioneer, Bayer, Syngenta, Pacific and Charoen Pokphand invest and conduct research on rice (see Chapter 3). However, little proportion of private research is being devoted to Thailand's major crops, especially rice, due to the difficulty in protecting intellectual property in open-pollinated seeds (Pray and Fuglie, 2001; FAO 2010). Based on the interviews we run in this dissertation, the private companies actually conduct research

to cover their business sections along the value chain of the rice sector. However, the research planning and execution in private research is separated from public research. The knowledge and research outputs are limitedly produced and disseminated for their business units and networks. Learning how rice research is governed and executed in the private sector can provide an understanding on different research and technology dissemination models that could accelerate impact generation process of rice research.

There are also methodological limitations in this dissertation. First and foremost is data availability. In Thailand as in other developing countries, the data at the governmental level is always disclosed. Therefore, data related to rice research system in Thailand is quite limited in term of accessibility. The NRCT consistently keeps record of R&D data, however, details on outcomes and impacts of the rice research are still limited. This can lead to future research aiming at developing a systematic data record and at improving monitoring and evaluation systems of rice research system in Thailand. Second, there are some limitations related to translating the conceptual framework to local context. The selection of reference literature in this dissertation could cause bias in data collection and analysis. As the study on IS in Thailand as in other developing countries has been at a primitive stage (Intarakumnerd et al., 2002), especially in the agricultural sector. The conceptual framework of this dissertation is composted from the literature in the context of developed countries context. In addition, the key informants understand and interpret the interview contexts differently according to their experience and fieldwork. Many of the key informants are not familiar with innovation system concepts. There is the need to guarantee clear communication between interviewers and the key informants being interviewed in order to ensure mutual understanding on the interview contexts that focuses on roles and contributions to research and innovation system in the rice sector. This recommendation emphasises the quality of communication which could be enhanced by sharing understanding on the interview contexts between interviewer and the key informants being interviewed. Moreover, the use appropriate language for the interviewees should be considered. Mackay and Horton (2003) addresses that the

technical jargons or terminologies discourage the interest of making research and findings more relevant.

6.6. Final reflections

The dissertation takes a broad perspective on the process of generating innovation and societal impact through agricultural research, from the production of primary research outputs to the various processes involved in realising final impacts. In this dissertation, I presented the contributions of agricultural research to the impact-generating process at different levels of aggregation in the rice research system in Thailand, ranging from the system as whole to programmes and individual researchers. The contributions of actors especially researchers and research to the innovation process are often determined in the impact studies literature. However, the management and governance system within the research system can also have an impact on innovation process (Jonkers, 2011). This dissertation shows the asynchronous development in responding to an AIS perspective, between each level in the research system and individual level. Although, he development of functions related to research governance at the system level is relatively behind, the reinforcement of the rice research system is complemented by the contribution of individual researchers.

The insights from this dissertation, therefore, provide the opportunity for conceptualising how an agricultural research system can improve its impact orientation at various levels and become better functioning as a whole. Instead of focusing only on the impact orientation at the individual, project level, or organisational level, it is important that public research initiatives should focus on managing research governance in a systematic and coordinated manner. From the findings, further action also requires a change in attitude and perception of researchers and policymakers who have actively performed the roles in the policy and strategic level of the highly centralised and hierarchical system to allow the research system to improve its impact orientation.

Summary

This dissertation aims to fill the gaps as regards how agricultural research contributes to the impact-generating process at the aggregate level using insights from the case study of the Thai rice research system. In the light of innovation system concept, the roles of agricultural research have been re-examined from having the central role in steering innovation to being an important element of an innovation system. The shifts in the roles of agricultural research have implications for the agricultural research system. The four empirical chapters represent interrelated the system level of the rice sector and rice research in three levels; research system, research program, and the individual researcher level. In Chapter 1, the overall research purposes, questions and research designs. The conceptual framework covers the topics on shifting perspective to the agricultural innovation system approach (AIS) and contributions of agricultural research to impact generation process.

Chapter 2 reviews actors, technologies, and policies related to rice sectors in Thailand, and how they interact in shaping the innovation system in the rice sector. The outstanding position of Thai rice in the global market results from an intensive knowledge flow among the different domains based on investing in public research and extensions. However, the interactions between the business and research domains are limited. It is important to stimulate knowledge flows and interaction among the different domains. The roles of the intermediate organization and the conditions to stimulate collaboration between different domains should be emphasized.

In Chapter 3, we seek to understand the development of the rice research system in Thailand developed overtime in the light of structural and functional development. The results show that the Thai rice research system has gradually developed in terms of structural characteristics and functions in response to the evolution of technological paradigms. The analysis indicates primarily that structural components of the research system have developed in line with functional needs and that the functions reinforce one another. This chapter suggests that, apart from structural development, the rice research system should focus on institutional arrangements, with the aim of

improving the efficiency and the effectiveness of public research, including decentralization of public sector decision-making and resource allocation, and facilitating participation by a broad range of actors.

In Chapter 4, we explore how individual and organizational characteristics determine different forms of engagement of researchers in impact-oriented activities using the case study of agricultural researchers performing research on rice in Thailand. Impact orientation of agricultural research is co-determined by factors at the different level. The study identifies of three different groups of researchers based on the activities related to the impact orientation of their research namely involving stakeholders in research, transferring knowledge and involving in policy process. The result shows that the factors including work experience, types of organization, attitudes towards impact-oriented activities and perceptions on supportive conditions in organizations were identified as determinants of the different degree of engagement in impact orientation practices of researchers. This chapter suggests that the organizational supportive conditions and incentives should pay more attention to facilitating and strengthening different kinds of interaction with stakeholders rather than only the volume of research outputs

In Chapter 5, we applied the combination of functional analysis with impact pathway analysis to study the roles and functions performed by individual researchers in facilitating the development, diffusion, and use of knowledge and technology based on the case study of Riceberry research programme. Several approaches and methodologies have been developed to gain insight into the impact-generating mechanisms to ensure impacts of agricultural research. We combine and integrate two approaches: the Function of Innovation System approach and the Impact Pathway approach to clarify the role of researchers by specifying and placing researcher activities at the interfaces between inputs, outputs, outcomes and impacts. the combination of functional analysis with impact pathway analysis the visibility of the de facto work of the programme leaders on a package of technical, organisational and institutional innovations rather than on a single innovation. This finding can certainly

be relevant in developing countries where the research system appears to have weak institutional arrangements and lacks incentives to contribute to the impact on society.

In Chapter 6, I discuss the cross-cutting issues across the empirical chapters, with a focus on the contribution of agricultural research to impact-generating processes at different levels of aggregation. Overall, the dissertation found the asynchronous development in responding to an AIS perspective, between each level in the research system and individual level. Although the development at the system level is relatively behind, the reinforcement of the rice research system is complemented by the contribution of individual researchers. I present the policy and practical implications of the findings, limitations of the research and future research, and final reflections of the dissertation.

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Chaniga Laitae
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Writing research proposal	WUR	2016	6.0
Research Methodology - From topic to proposal	WASS	2015	4.0
Oral presentation in Ag-econ seminar 'Evolution of agricultural research systems in developing countries: a case study of rice research system in Thailand'	Faculty of Economics, Kasetsart University Thailand	2019	1.0
Oral presentation in Ag-econ seminar 'Rethink the role of research in impact pathway: Evidence from Riceberry project'	Faculty of Economics, Kasetsart University Thailand	2019	1.0
STEPS Centre Summer School on pathways to sustainability	University of Sussex, UK	2018	3.0
EU-SPRI Summer School in Oslo: The Science System in the 21st Century	University of Oslo, Norway	2018	1.5
Information Literacy	WUR Library	2017	0.6
B) General research related competences			
WASS Introduction course	WASS	2015	1.0
Systematic Approaches to Reviewing Literature	WGS	2016	4.0
Questionnaire Construction (YRM-65300)	WUR Modular Skills Training	2017	1.5
Scientific Writing	Wageningen In'to languages	2019	1.8
Academic Publication and Presentation in the Social Sciences	WASS	2020	4.0
The Essentials of Scientific Writing and Presenting	Wageningen In'to languages	2016	1.2
Masterclass Social Network analysis	WASS	2019	0.3
C) Career related competences/personal development			
Reviewing Scientific Paper	WGS	2016	0.1
Project & Time Management	WGS	2016	1.5
Total			**32.5**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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About the author

Chaniga Laitae was born in 1985 in Sukhothai, a historical town in Thailand. Chaniga obtained her bachelor's degree in Zoology at Kasetsart university, Thailand in 2008. After her bachelor's degree, she enrolled in the Interdisciplinary Graduate Programs, Resource Management at Kasetsart University. During her master's years, she experienced the enjoyable learning curves in interdisciplinary research field. She also worked as a research assistant in the Center for Applied Economics Research for several research projects. She developed research interests in impact study of research in an agricultural context. In addition, she developed skills on research management especially, monitoring & evaluation study. After couple years working as a research assistant, Chaniga obtained the Royal Thai Government scholarship fully funded to pursue her PhD in Knowledge, Technology and Innovation group, Wageningen University and Research. Chaniga is now working as a policy analyst in the Office of National Higher Education Science Research and Innovation Policy Council in Thailand.

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