FACULTY OF ECONOMICS AND
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An Operational Analysis of the Rice Value Chain in the Ayeyarwaddy Region, Myanmar

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"A clear vision, backed by definite plans, gives you a tremendous feeling of confidence and personal power."

(Brain Tracy)

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Summary

This dissertation investigated on the operational analysis of the rice value chain in the Ayeyarwaddy Region, Myanmar. Agriculture plays a major role in Myanmar by ensuring food security as well as in the provision of employment and income for a growing population. Among agricultural crops, rice is the most important agricultural product in the country, accounting for about half of the cultivated land. The agricultural sector has suffered persistently from insufficient investment in technology transfer, research and extension services, infrastructure development, value chain upgrading and marketing according to IFAD (2017). Furthermore, farmers have not received remunerative prices for their products, leading to declining rural income. The value chain development is an approach to reduce the rural poverty and has been adopted by governments, donors, and NGOs (World Bank, 2014). The term value chain refers to the full range of activities that are required to bring a product (or a service) from conception through the different phases of production to delivery to final consumers and disposal after use (Kaplinsky and Morris, 2002). Based on the principal challenge areas and strategic objectives that Myanmar especially needs to address and consider for developing country's rice sector identified by the Ministry of Agriculture and Irrigation (MOAI, 2015b), three different studies (Chapters 2 to 4) are investigated for this dissertation.

In Chapter 2, we follow the framework of Trienekens (2011) and start from the network structure of the rice value chain to examine (1) the socio-demographic characteristics of the actors in the chain and the value addition in the different stages via a profitability analysis; (2) the major constraints that limit the operations of each actor. Therefore, we studied the operational constraints of the rice value chain in the Ayeyarwaddy Region. The contributions of Chapter 2 are threefold. Firstly, we estimate the marketing costs and margins to evaluate the profits of the different actors involved in the rice value chain after mapping the rice value chain in the Ayeyarwaddy Region, Myanmar. Secondly, we describe the operational constraints of these different actors and the socio-demographic characteristics of the actors in the rice value chain. Lastly, we link the socio-demographic characteristics and operational constraints to the profitability of the different actors in the rice value chain. The gross marketing margin across the global value chain is very wide and is not equally distributed over the different actors. Not all actors receive a reasonable profit

margin. The rice miller is by far the most profitable actor whereas the farmers are the most vulnerable actors in the value chain given their moderate profit margin and the large number of constraints imposed. The actors suffer especially from material input constraints, production constraints, financial constraints and distributional and institutional constraints. All these constraints have a significant and negative impact on the profitability of the actors and hinder the further development of the value chain. The described constraints highlight the array of key issues that must be resolved to upgrade the rice value chain.

The impact of uncertainties and risks can change the sustainability of the value chains, potentially affecting the performance of the chain. In an agricultural (rice) value chain, uncertainty can emerge either from internal or external source in the supply chain. Uncertainty can be described as the inability to predict something (Milliken, 1987). According to Knight (1971), if it is not possible to quantify a probability of occurrence, it is called uncertainty. According to Miller (1993), uncertainty refers to '*the unpredictability of environmental or organizational variables that have an impact on corporate performance*'. Agricultural food supply chain has unique characteristics with sources of uncertainty factors which are different from those of other supply chains. Many sources of uncertainty for food supply chains appear due to variable harvests and production yields, perishability of products and the huge impact of weather conditions on production and customer demand (Jack and Adrie, 2002). Uncertainties in a supply chain may cause delays, lead to a bottleneck and may hinder the performance of the entire supply chain. Therefore, Chapter 3 investigates the impact of uncertainty on the performance of the rice supply chain in the Ayeyarwaddy Region, Myanmar and contributes threefold to this thesis. First, we identify the sources of uncertainty perceived by the different actors in the rice supply chain in the Ayeyarwaddy Region, Myanmar. Second, we measure the rice supply chain efficiency as a measurement of supply chain performance. Last, we study the impact of uncertainty on supply chain efficiency to understand the challenges of the supply chain the region is dealing with and to identify solutions to improve the supply chain operations. The actors in the supply chain suffer from the specific uncertainty sources depending on their role in the supply chain. Farmers face negative effects of climate and uncertainty in planning and control. The millers in particular significantly suffer from the process uncertainty and the distributors face the adverse impact of demand uncertainty. In particular, both the climate and planning and control uncertainty present in the early production stages of the supply

chain and have a negative and significant impact on the different types of efficiency leading to the poor performance of the entire supply chain.

The rice production is an essential stage not only for the entire value chain but also for the food security of Myanmar. Increasing productivity is the important consideration to improve the competitiveness of Myanmar's rice in both domestic and international markets. The production of rice cultivation in Myanmar remains low while there is still a high potential for a production increase. According to Saysay (2016), rice production and supply is sensitive to profitability and improving profitability provides incentives to increase the production and the marketable surplus. The best and most effective way to improve productivity can be realized via a more efficient utilization of scarce resources. Efficient farm practices can enhance productivity, the farmers' profit and the amount of rice marketed (Saysay, 2016). Moreover, the estimation of efficiency without clearly identifying important socio-economic and demographic, institutional and policy variables, has limited importance for policy and management purposes (Saysay, 2016). In Chapter 4, the efficiency of the rice production of the farmers is investigated and this chapter contributes twofold. First, we analyze the profitability of the rice production in the Ayeyarwaddy Region. Second, we estimate the overall technical, pure technical, scale, allocative and economic efficiency of the rice farmers in the Ayeyarwaddy Region. Last, we determine the influencing factors on these different efficiencies of the rice farmers. Although the farmers are somewhat technically efficient, they are not allocatively efficient in their rice production. Therefore, farmers suffer seriously from the economic inefficiency due to a very economic efficiency score. More than 50% of the economic inefficiency lead to the farmers earning lower income. They cannot generally cover the cost of rice production. According to the results of the Tobit regression analysis, farm-farmer related variables i.e. age, education and experience impact on the farm efficiency. The variety used (farm-production related variable) and the extension services received by the farmers (farm-institution related variable) also impact the technical, scale and economic efficiency of the rice farmers.

As a conclusion, Chapter 5 summarizes the general conclusions of this PhD based on three different studies presented in chapters 2 to 4 and highlights a number of avenues for further research.

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List of Abbreviations

ASEAN	Association of South East Asian Nations
CRS	Constant returns-to-scale
DEA	Data Envelopment Analysis
DEAP	Data Envelopment Analysis (Computer) Program
DMUs	Decision Making Units
DOA	Department of Agriculture
EU	European Union
EViews	Econometric Views
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Databases
FOB	Free on Board
GDP	Gross Domestic Product
GMM	Gross Marketing Marin
GNI	Gross National Income
ha	Hectare
HCMC	Ho Chi Minh City
HDI	Human Development Index
IFAD	International Fund for Agricultural Development
IRS	Increasing returns-to-scale
kg	Kilogram
LR test	Likelihood Ratio test
MADB	Myanmar Agricultural Development Bank
MAPCO	Myanmar Agribusiness Public Corporation
MKK	Myanmar Kyat
MOAI	Ministry of Agriculture and Irrigation
MOALI	Ministry of Agriculture, Livestock and Irrigation
MRF	Myanmar Rice Federation
MT	Metric Tons
NGOs	Non-governmental Organizations
NMM	Net Marketing Margin
PPP	Purchasing Power Parity
RAVC	Return Above Variable Cost

RQ	Research Question
RSC	Rice Specialized Companies
SFA	Stochastic Frontier Analysis
SPSS	Statistical Package for the Social Sciences
TGMM	Total Gross Marketing Margin
UNDP	United Nations Development Programme
USD	United States Dollar
USDA	United States Department of Agriculture
VCA	Value Chain Analysis
VRS	Variable returns-to-scale
WTO	World Trade Organization

1

Introduction

Agriculture is the backbone of the economy of Myanmar not only contributing to the overall economic growth of the country but also sustaining a standard of living for more than 70 per cent of the Myanmar population. Among the agricultural crops, rice is the most important crop of Myanmar. It dominates the agricultural sector, which is the largest and most productive part of the economy and changes in rice production have a direct and profound influence on the entire population. Myanmar's rice output must continually increase to feed the growing populations and boost the country's economy. The rice industry has a main challenge for increasing its performance and sustainability which may improve the food security and reduce the poverty in the country. It is needed to study the challenges for increasing the performance and sustainability of the rice industry. To that purpose, this dissertation investigates three different aspects presented in chapters 2 to 4, related to the operational analysis of the rice value chain which may lead to the food security and rural poverty reduction in Myanmar. The introduction section briefly introduces the general introduction to the situation of agriculture and rice industry in Section 1.1. Section 1.2 provides the literature review related to the different studies contributed to this dissertation. The overview of the different chapters and contribution of this dissertation are presented in Section 1.3.

1.1 General Introduction

In this section, we give a general introduction related to the agricultural sector in Myanmar. In Section 1.1.1, the importance of the agricultural sector and the rice industry in Myanmar is highlighted. In Section 1.1.2, we detail the three main functions in this supply chain to illustrate the flow of the rice from the production to the consumption in both domestic and international, i.e. the paddy and rice production (Section 1.1.2.1), the rice milling sector (Section 1.1.2.2) and the rice export distribution (Section 1.1.2.3), respectively. Section 1.1.3 discusses the challenges for this industry and the motivation for conducting the research included in this dissertation.

1.1.1 Importance of agricultural sector and rice industry in Myanmar's economy

Agriculture plays a major role in Myanmar's society by ensuring food security at community and national levels as well as in the provision of employment and income for a growing population. Agriculture is essential to the domestic economy of Myanmar and is also the main employment factor in rural Myanmar. The agricultural sector is considered as one of the major driving forces for economic growth and the heart for improving of social wellbeing (World Bank, 2014). Agricultural sector which generates foreign exchange earnings through agricultural export and to boost rural development plays as an essential role in economic growth and poverty reduction. The agricultural sector is the mainstay of the economy of Myanmar and more than half of the population is directly employed in farming. In 2014-2015, 22.1 % of GDP came from agriculture, 8.5% from livestock and fisheries and 0.2% from forestry (MOAI, 2015a). The importance of agriculture in the economy as an employer will diminish in the coming years as a result of structural transformation. However, the sector will continue to play a remarkable role in reducing poverty in Myanmar for many years to come (World Bank, 2014).

Rice is in particular among the three leading food crops of the world, with corn and wheat being the other two. Rice is a plant that is well suited to the tropical climate condition. According to FAO (2004), rice is the important staple food for 17 countries in Asia and the Pacific, nine countries in North and South America and eight countries in Africa. Nutritionally, it contains 80% carbohydrates, 7-8% proteins, 3% fat, and 3% fibre (Juliano, 1985). Rice provides 21% of global human per capita energy and 15% of per capita protein. Rice, the major staple food among crops grown in Myanmar, is central to the lives of millions of people in Myanmar. Rice is the country's most important agricultural product by far, accounting for about half of all cultivated land. According to Figure 1.1, paddy (rice) has the highest percentage share of total cultivated area (46%) among crops grown in Myanmar. Labor is the most important resource in the rice industry. In addition, most of the household income is earned from rice farming and related activities, especially in major rice growing area of Ayeyarwaddy, Bago, and Sagaing Regions in Myanmar.

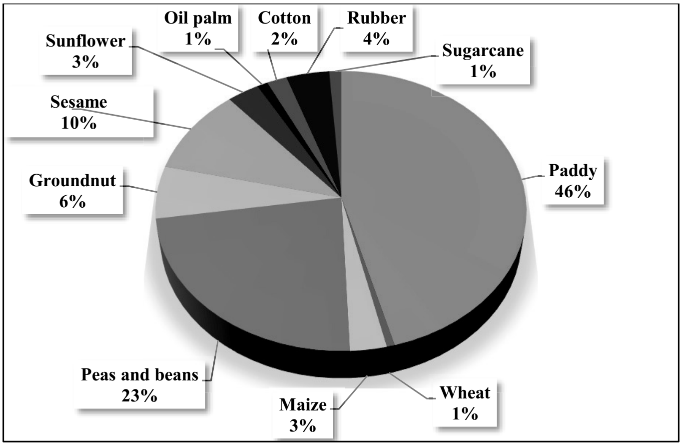


Figure 1.1 Percentage shares of total cultivated area among crops grown in Myanmar in 2015

Source: MOALI (2016)

1.1.2 Major parties in the value chain of the rice industry in Myanmar

In Myanmar, rice is a major staple crop and almost all of the people in the country mainly depend on rice for their nutrition. On the consumption side, rice contributes about 66 percent of the population's daily calorie intake (Myint, 2018). Moreover, rice provides food security and poverty reduction in Myanmar and contributes export earnings to the economy of the country. Therefore, increasing rice production is playing as an important role for the socioeconomic development of Myanmar. In order to understand the rice industry and the problems encountered, we describe in this section the major parties, i.e. the paddy and rice production (Section 1.1.2.1), the rice milling sector (Section 1.1.2.2) and the rice export distribution (Section 1.1.2.3).

1.1.2.1 Paddy and rice production in Myanmar

On the production side, out of the sown area of paddy in Myanmar, 38 percent is grown under rain-fed conditions, followed by 30 percent under irrigated system, 17 percent under deep water, submerged and salt affected ecosystem, 12 percent in drought prone area and only 3 percent of paddy cultivation was in upland region (MOAI, 2015b; San, 2017). As shown in Figure 1.2, the sown areas of paddy increased from 6.86 million hectares in 2004-

05 to 7.21 million hectares in 2015-16. The production also increased from 24.75 million metric tons in 2004-05 to 27.16 million metric tons in 2015-16. The paddy yield per hectare increased from 3.64 MT in 2004-05 to 4.07 MT in 2010-11which is the highest for 11 years (cf. Figure 1.3). Yield per hectare decreased again to 3.83 MT in 2011-12 and increased again to 3.94 MT per hectare in 2014-15 and 3.93 MT per hectare in 2015-16. However, compared to the paddy yields of other ASEAN countries, Myanmar's paddy yield was the second lowest one after Cambodia from 2010 to 2012 (cf. Figure 1.4).

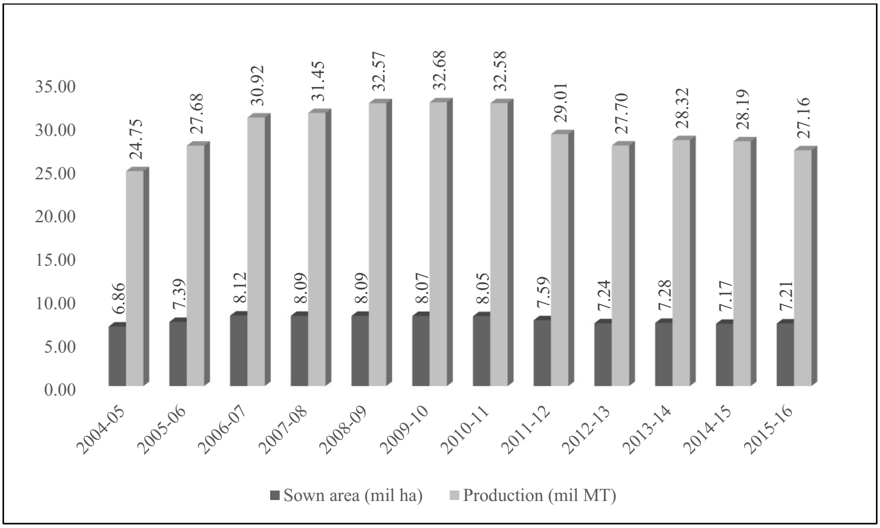


Figure 1.2 Sown area and production of paddy in Myanmar from 2004-05 to 2015-16

Source: MOALI (2016)

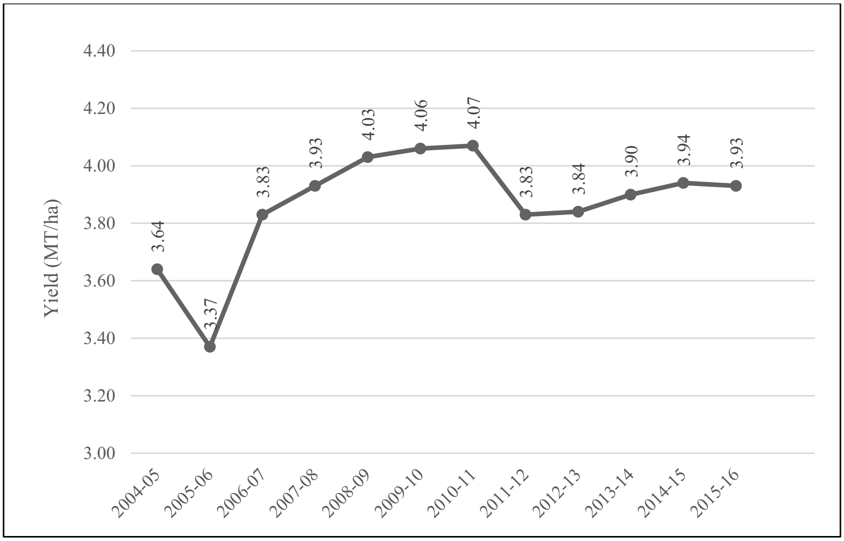


Figure 1.3 Paddy yield per hectare (in MT) in Myanmar from 2004-05 to 2015-16

Source: MOALI (2016)

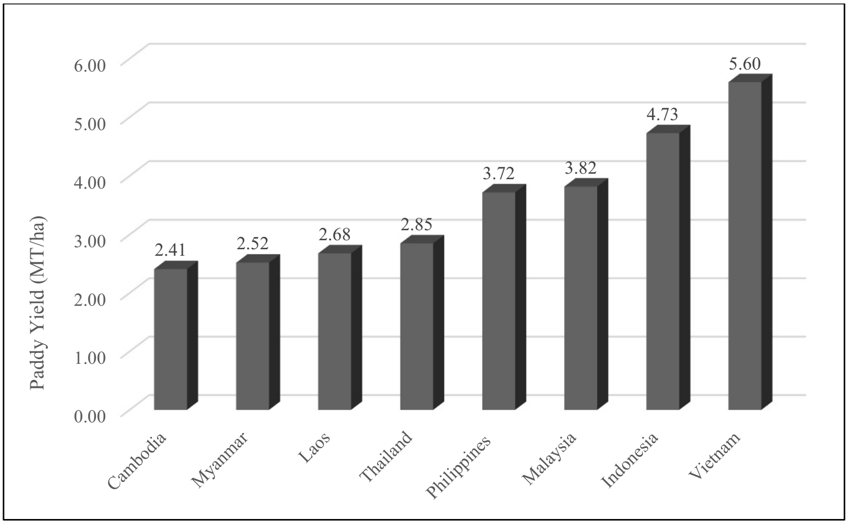
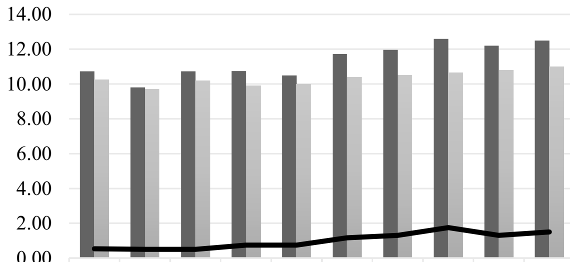


Figure 1.4 Paddy yield per hectare (in MT) in ASEAN countries (Average in 2010-2012)

Source: MOAI (2015b)



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Milled rice production (mil MT)	10.73	9.80	10.73	10.75	10.50	11.72	11.96	12.60	12.20	12.50
Consumption and residuals (mil MT)	10.25	9.70	10.20	9.90	10.00	10.40	10.50	10.65	10.80	11.00
Export (mil MT)	0.54	0.50	0.50	0.75	0.75	1.16	1.30	1.75	1.30	1.50

Milled rice production (mil MT) Consumption and residuals (mil MT)

Export (mil MT)

Figure 1.5 Milled rice production, consumption and residuals and export (in mil MT) in Myanmar from 2007-08 to 2016-17

Source: USDA (2009-2016)

The production, consumption and export of milled rice from 2007-08 to 2016-17 are illustrated in Figure 1.5. The production of milled rice increased from 10.73 million metric tons in 2007-08 to 12.50 million metric tons in 2016-17. Myanmar exports rice surplus resulting from the deducting the consumption and residuals from the total milled rice production (cf. Figure 1.5). The export volume increased from 0.54 million metric tons in 2007-08 to 1.50 million metric tons in 2016-17. However, Myanmar has the lowest profits from the rice production compared to those of other rice growing countries in Asia (Zorya, 2016). Farm profits in Myanmar are the lowest in Asia as a direct result of low productivity of land and labour. In 2013-2014, the net profit from producing monsoon paddy averaged \$114/ha. In general, farm profits are not enough to raise households' per capita income above the regional rural poverty line (Zorya, 2016). This also indicates that the potential of the agricultural sector has not yet been realized for the purpose of poverty reduction. Appendix 1.A illustrates and interprets several facts and figures regarding the poverty and development in Myanmar in recent years as well as information about other neighbouring countries to show the significant differences between the countries.

1.1.2.2 Rice milling sector in Myanmar

The rice industry is composed of not only paddy production but also milling, trade, distribution, and other rice-based food processing activities. Out of these activities, rice milling is a major manufacturing sector in Myanmar. In the food and beverage sector, rice milling occupied for more than 60% of the establishments in Myanmar (Kudo et al., 2012). According to the report of the World Bank (2014), the rice milling sector operates with obsolete processing machines which cause about 15-20 % of the losses in quality and quantity during the milling. The average milling ratio (average 2008-2011) of the rice mills in Myanmar is estimated to be 60% which is lower compared to other Asian countries such as Vietnam and Philippines (63%), Cambodia and Indonesia (64%), Malaysia (65%), Thailand (66%) and China (70%) (World Bank, 2014). In Myanmar, most of the paddy is milled by hullers especially in the villages, and marketable rice is processed by modern medium and large-sized mills located in the towns and cities (Aung, 2012). Table 1.1 illustrates that there were total 1,362 medium-sized commercial mills operating with the milling capacity of more than 15 tons/day (on average 25.41 tons/day) in Myanmar in 2013. According to MOAI (2015b), out of these mills, 348 rice mills were from 30 to 64 years of age and 68 were more than 65 years old. Therefore, these rice mills are outdated and need to be upgraded or replaced by new ones to improve capacity and efficiency. Among them, most of the rice mills can process milled rice of Grade C (25% broken rice). Sixty-four rice mills are suitable to process super quality rice (Grade A). Across the Regions and States, the Ayeyarwaddy Region occupies the highest numbers of the rice mills (587 numbers) and rice mills of Grade C are the majority (268 numbers or 45.66%) followed by Grade D (180 numbers or 30.66%) (cf. Table 1.1). Only 2.56% of the rice mills are rice mills of Grade A in the Ayeyarwaddy Region. According to San (2017), the numbers of large modernized mills and processing plants are increasing as a result of the Rice Specialized Companies (RSC) in the rice value chain. Moreover, branded package rice marketing is also domestically increasing due to increasing number of supermarkets and minimarkets in large and populated cities of Myanmar (San, 2017). Therefore, the supply of packed and branded rice is becoming higher to fulfil the increasing demand.

Table 1.1 Frequency and milling capacity of registered rice mills in different Regions and States of Myanmar in 2013

Region/State	Grade A (1-5% broken rice)		Grade B (10-15% broken rice)		Grade C (25% broken rice)		Grade D (35% broken rice)		Total	
	No.	Milling Capacity	No.	Milling Capacity	No.	Milling Capacity	No.	Milling Capacity	No.	Milling Capacity
Yangon	17	1564	46	2327	135	2386	27	405	225	6682
Ayeyarwaddy	15	635	124	3860	268	6110	180	5049	587	15654
Bago (East)	8	282	14	619	30	890	79	1719	132	3510
Bago (West)	16	479	34	874	48	943	55	859	153	3155
Mandalay	-	-	-	-	21	315	-	-	21	315
Mon	-	-	2	45	30	562	-	-	32	607
Sagaing	8	416	45	1203	62	1074	48	1049	163	3742
Tanintharyi	-	-	-	-	-	-	4	70	4	70
Kachin	-	-	-	-	6	90	-	-	6	90
Kayar	-	-	-	-	39	780	-	-	39	780
Total milling capacity/day	64	3376	265	8928	639	13150	393	9151	1362	34605

Note: Milling capacity per day is measured in ton and assumed 24 hours of operation.
Source: MRF (2014) and MOAI (2015b)

1.1.2.3 Characteristics of the international rice trade

In this section, we will elaborate on the characteristics of the international trade of rice. The main goal is to identify the market access conditions, the potential of Myanmar's rice exports in international trade and the essential elements of global supply and demand of Myanmar's rice. Myanmar could export rice about three-fourths of the world rice exports and was the major rice exporting country in the world during the first half of the twentieth century (Kenneth et al., 1998). The bulk of these exports are sold to Ivory Coast, Guinea, and Burkina Faso in Africa and to Indonesia, Bangladesh, and the Philippines in Asia. EU has also been the customer of Myanmar's rice since 2004 as shown in Table 1.2. The government's target for rice exports is to reach 4 million metric tons by 2019-2020 (cf. Table 1.3). Myanmar's paddy production stood as 6th rank among top ten paddy producing countries with the amount of 1,500 thousand metric tons (1.5 million metric tons) in the world in 2016-17 as shown in Figure 1.6 (World Rice Production, 2017). However, Myanmar achieves very low value of 0.113 billion USD from exporting rice because of low price per metric ton compared to other rice exporting countries (cf. Figure 1.7). The types of Myanmar's exported rice are mostly of low value 25% broken rice and white rice.

Myanmar's rice is cheaper than rice of comparable quality from Vietnam, India and Pakistan as shown in Table 1.4.

On the other hand, Myanmar is located between two of the most highly-populated countries in Asia, India and China, which are vast markets that can be tapped for rice and rice-based products. The increasing trend in rice demand is an opportunity for Myanmar to increase rice production for both regional and global exports. Moreover, the country must diversify the type and quality of its rice for export including aromatic, jasmine, glutinous, and parboiled rice. The global rice demand projections are good signals for Myanmar to develop its rice sector to gain a significant share in international trade. By 2020, China is expected to import 4 million metric tons of rice (MOAI, 2015b). The EU has likewise offered an incentive for Myanmar to enter the European market to sell high-quality rice. Also, the rising demand for rice in Africa gives Myanmar the signal to continue its increasing trade with the region for 25% broken rice. World Bank (2014) stated that Myanmar can potentially increase more than double in the rice exports by increasing rice production and diversifying many type of exported rice. In addition, opening the rice milling sector to foreign direct investments and reducing export procedure costs can help many rural poor to escape poverty. Improving agricultural productivity and promoting rice exports are top priorities for the Government of Myanmar. The current rice export strategy favors the production of low quality rice, which is largely sold to Africa and China. Consequently, farmers have earned minimal profits and agribusinesses have skipped necessary investments (World Bank, 2014). Opening the rice mills to foreign direct investments is a vital step to take to increase quality and volumes of rice export. To boost Myanmar's rice export competitiveness, it is essential to improve the infrastructure and to reduce the export procedure costs (World Bank, 2014).

Table 1.2 Myanmar's rice exports by destination, 1995-2012 ('000 MT)

Destination	1995-1999	2000-2004	2005-2009	2008	2009	2010	2011	2012
EU	0	15	*	*	*	0	12	28
Former Soviet Union	0	0	*	0	2	11	19	44
AFRICA	**43**	**195**	**261**	**196**	**899**	**318**	**506**	**460**
-Burkina Faso	0	11	9	10	29	64	71	82
-Cameroon	2	13	14	25	24	15	37	21
-Guinea	7	31	70	44	246	85	125	173
-Ivory Coast	2	49	73	25	252	95	122	125
-Sierra Leone	5	18	18	20	44	0	4	9
-Togo	0	4	13	22	40	11	33	6
ASIA	**170**	**264**	**129**	**403**	**150**	**156**	**276**	**72**
-Bangladesh	10	108	99	385	70	116	215	0
-China	0	1	0	0	1	0	0	13
-Indonesia	122	132	5	0	11	5	2	10
-Philippines	27	2	9	0	47	16	13	33
TOTAL	**222**	**484**	**391**	**598**	**1052**	**485**	**816**	**605**

Note: * Less than 500 MT

Source: MOAI (2015b)

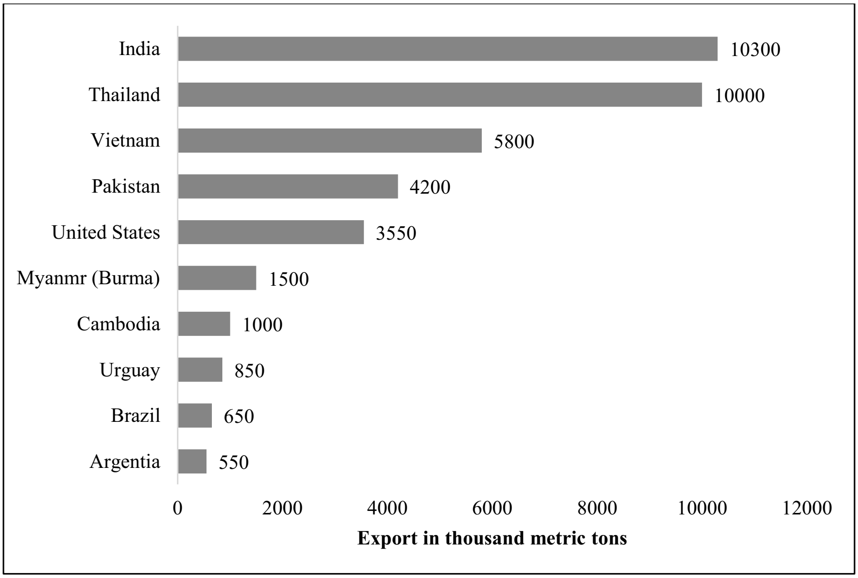


Figure 1.6 Principal rice exporting countries worldwide in 2016/2017

Source: Workman (2017)

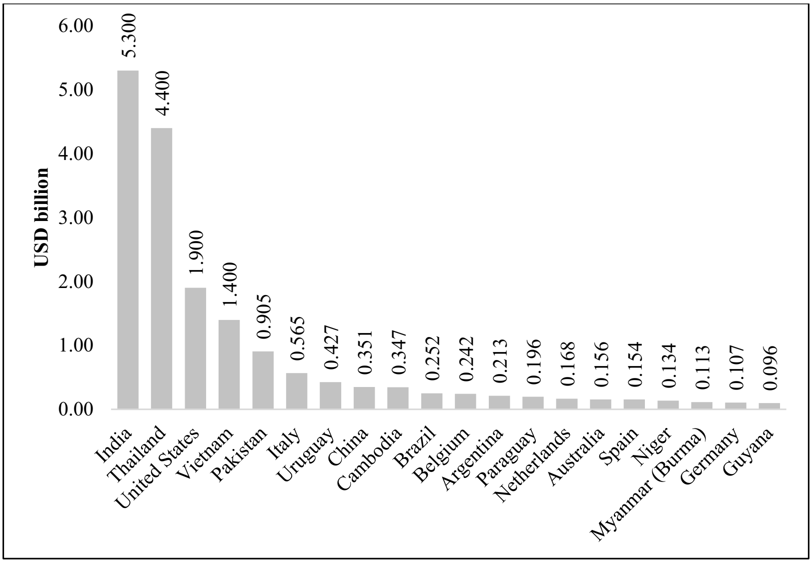


Figure 1.7 Principal rice exporting countries worldwide in 2016/2017

Source: Workman (2017)

Table 1.3 Myanmar's recent rice exports in average ('000 MT)

Year	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Export ('000 MT)	750	750	1163	1300	1750	1303	1500

Source: World Bank (2014)

Table 1.4 Selected export prices, 25% broken rice, FOB, USD/MT

Year and Month	Myanmar	Vietnam	Pakistan	India
2011				
-October	400	520	405	410
-December	345	425	390	385
2012				
-March	360	415	415	375
-June	350	415	415	395
-September	390	400	400	414
-December	350	365	365	390
2013				
-March	380	365	380	415
-June	370	340	410	415

Note: FOB Bangkok, HCMC, and Yangon at the end of the month

Source: World Bank (2014)

1.1.3 Problem statement

The agricultural sector has suffered persistently from insufficient investment in technology transfer, research and extension services, infrastructure development, value chain upgrading and marketing (IFAD, 2017). Furthermore, farmers have not received remunerative prices for their products, leading to declining rural income. The value chain development is an approach to reduce the rural poverty and has been adopted by governments, donors, and NGOs (World Bank, 2014). According to MOAI (2015b), the principal challenges that Myanmar especially needs to address to develop its rice sector are: 1) the worsening effects of climate change which increase the farmers' vulnerability to drought, flood, salinity, heat waves and extreme weather events; 2) limited availability of, and farmers' access to improved technologies and management practices; 3) a weak extension and education system; 4) limited access to financial services; 5) limited facilities for postharvest handling and processing; 6) inadequate infrastructure, particularly for irrigation, power, and transport; 7) uncertain security of land tenure; 8) volatility of paddy price that contributes to low income of farmer; 9) a poorly integrated value chain, from rice production to trade and markets; and 10) policies that hamper investments in the rural and rice sectors. Based on the challenges mentioned above, the Ministry of Agriculture, Livestock and Irrigation set five strategic objectives to guide the key themes and actions to achieve Myanmar's vision of its rice sector (MOAI, 2015b), i.e.

1) To improve the competitiveness of Myanmar's rice in both domestic and international markets through increased productivity;
2) To improve the adaptation of rice farming to the effects of climate change and to enhance farmer's capacity to cope with associated risks;
3) To increase the rice food quality and safety and the competitiveness and fairness in domestic and international markets;
4) To create a positive effect on the well-being and capacity of smallholder farmers, including women and children, in the context of long-term changes in demography, farm size, and labor supply; and
5) To reduce the weaknesses along the rice value chain, thus improving efficiency and minimizing postharvest losses, all to increase the market value of rice production and improve rice food quality.

According to the challenges and strategic objectives mentioned above, it is noticed that the rice value chain in Myanmar is not well integrated and improvements related to its efficiency are required. The rice value chain in Myanmar is still far from perfect and limited by weaknesses which causes high transaction costs for all actors (MOAI, 2015b). In order to uncover insight in the weaknesses of this value chain, a value chain analysis should be conducted by mapping the major constraints from an operational perspective. These constraints faced by the actors can hinder the profitability and the further value chain development and are possibly imposed by the external parties. The operational constraints of each actors in the rice value chain should be carefully mapped in order to suggest not only how and who is the best placed to fix them but also arrive at a rational sequence or actions that need to be taken in tandem. Moreover, the required different interventions and response from the government and private partners can be suggested for upgrading the rice value chain.

Moreover, another consideration is that the impact of uncertainties and risks can change the sustainability of the value chains, potentially affecting the performance of the chain. In an agricultural (rice) value chain, uncertainty can emerge either from internal or external source in the supply chain. The unique characteristic of agri-food supply chain is that the biological agricultural production is related to nature, weather and uncontrollable natural forces, perishability of products and environmental concerns (Wijnands and Ondersteijn, 2006). Further the demand in agri-food supply chains is characterized by a high variability in the consumer demand (Taylor and Fearne, 2006). Some sources of uncertainty of rice supply chain are related to the production yields and the huge impact of climate conditions on upstream, and downstream activities (van der Vorst and Beulens, 2002). Uncertainty is inevitable in the supply chain operation. According to van der Vorst et al. (2000) and Dong (2006), along with the huge number of the actors, the operational complexity of the agri-food supply chain (such as the seasonality in production, long/fixed production lead times, varying quantity and quality standards of products, trade and buffer stock traceability) mostly expose the chain to severe disruptions. These types of uncertainty can affect the efficiency of the entire supply chain leading to the poor performance of the chain.

According to the first strategic objective for the rice sector in Myanmar (MOAI, 2015b), increasing productivity is an important consideration to improve the competitiveness of Myanmar's rice in both domestic and international markets. The production of rice cultivation in Myanmar remains low while there is still a high potential for a production increase. According to Saysay (2016), rice production and supply is sensitive to profitability and improving profitability provides incentives to increase the production and the marketable surplus. The best and most effective way to improve productivity can be realized via a more efficient utilization of scarce resources. Efficient farm practices can enhance productivity, the farmers' profit and the amount of rice marketed (Saysay, 2016). Improving the productivity of the rice industry could contribute to a poverty reduction leading to hunger eradication, national food security and economic development (FAO, 2004). Therefore, the efficiency of the farmers in terms of technically, scale and economically is a very important consideration in the rice industry.

The investigation on the operational constraints in the rice value chain, the uncertainty and its impact on the rice supply chain performance and the efficiency of the rice production by farmers can help how to overcome/realise these challenges/objectives of the rice sector to improve the food security and rural poverty reduction. According to Raju and Chand (2008), the uncertainty factors related to natural disasters, yield and price in agricultural products, imperfect markets etc. not only impact on farm livelihoods and incomes but also constrain or challenge the viability of the agriculture sector and its potential to become a part of the solution to the problem of widespread rural poverty. Therefore, the uncertainty may be the source of the constraints. The efficiency of the rice production and the good performance of the rice supply chain are important for the development of the rice value chain. Moreover, we should consider the constraints and uncertainty impacted the rice value chain so that the possible solutions can be imposed for the value chain development in the rice industry of

Myanmar. Therefore, this dissertation constructed by three different studies has been motivated in order to discover the possible solutions and recommendations to the findings of operational analysis of the rice value chain that may support to the food security and rural poverty reduction in Myanmar.

1.2 Literature Review

1.2.1 Value chain and value chain structure

The term value chain refers to the full range of activities that are required to bring a product (or a service) from conception through the different phases of production to delivery to final consumers and disposal after use (Kaplinsky and Morris, 2002). According to Nang'ole et al. (2011), a value chain focuses on a single firm and involves 1) the conception and design stage; 2) the acquisition of inputs; 3) production, marketing and distribution activities; and 4) the performance of after-sale services. The broad value chain approach starts from the production system of the raw materials used to produce a product. Nang'ole et al. (2011) stated that it also includes linkages with other actors involved in value adding activities i.e., trading, assembling, processing and providing business development services such as credit and market information. The value chains can be a different type. Based on the idea of governance, there are two distinguished types of value chains: Buyer-driven chains and Producer-driven chains (Kaplinsky and Morris, 2002). Governance refers to the controlling and monitoring of the implied rules and interactions between the different actors in the value chain by setting parameter regarding products, processes and qualifications. Kaplinsky and Morris (2002) categorized it as buyer-driven chains, when this governance role is played by a buyer at the top of the chain. The producer-driven chains describe the governing role to be played by the leading producer of the chain and are most likely to be present in capital-and technology-intensive environment. The difference in value chains not only within and between sectors, but also the international, national and local context is an important factor to take into account (Kaplinsky and Morris, 2002).

Bammann (2007) identified three important levels in the value chain, i.e.

- *Value chain actors*: The actors of the chain who directly deal with the products, i.e. produce, process, trade, and own them.
- *Value chain supporters*: The services provided by various actors who never directly deal with the product, but whose services add value to the product.

- *Value chain influencers:* The regulatory framework, policies, infrastructures, etc.

Kaplinsky and Morris (2002) stated that the value chains differ within and between sectors. Thereby, the context in which they operate alters too. They ranked several issues and factors to focus on when analyzing a supply chain: A first and far most important step is the understanding of the market. To be able to conduct a secure value chain analysis, Kaplinsky and Morris (2002) considered firstly the way a chain is looked at and determines which relations and actions are to be the key processors, functions, roles etc. Secondly, mapping value chains is a second important consideration. This involves the determination of constraint, the selection of appropriate decision variables and the assignment of amount and values to the respective variables for each actor or step in the value chain.

Value Chain Analysis

According to Jurevicius (2013), value chain analysis (VCA) is a process in which a firm organises its primary and support activities that add value to its final product and then analyze these activities if they can reduce costs or can increase differentiation.

The value chain approach is mainly a descriptive tool to look at the interactions between different actors (M4P, 2008). Value chain analysis has one advantage because it forces the analyst to consider both the micro and macro aspects of production and exchange activities. The commodity-based analysis can provide better insights into the organizational structures and strategies of different actors, which is the analysis that will be used in our study. In addition, another analysis is an understanding of economic processes which are often studied only at the global level (often ignoring local differentiation of processes) or at the national/local levels (often diminishing the larger forces that shape socio-economic change and policy making) (M4P, 2008).

Kaplinsky and Morris (2002) stressed that there is no "correct" way to conduct a value-chain analysis; rather, the approach taken fundamentally depends on the question that is being asked. However, four aspects of value-chain analysis of agriculture are particularly important. At the most basic level which is the first step, a value chain analysis systematically maps the actors participating in the production, distribution, marketing, and sales of a particular product (or products) (M4P, 2008). Second, value chain analysis can play a key role in identifying the distribution of benefits of actors in the chain. It means that it is possible to determine who benefits from participation in the chain and which actors could benefit from increased support or organization by using the analysis of margins and profits within the chain. Third, value chain analysis can be used to examine the role of upgrading within the chain. Upgrading can include quality and product design improvements or diversification in the product lines served to gain the higher value. In addition, an analysis of the upgrading process includes an assessment of the profitability of actors within the value chain as well as information on limitations that are currently present. Finally, value chain analysis highlights the role of governance internally or externally in the value-chain. Governance in a value-chain refers to the structure of relationships and coordination mechanisms between actors.

According to the framework of Trienekens (2011), the value chain analysis starts from the network structure of the rice value chain to examine firstly the socio-demographic characteristics of the actors in the chain and the value addition in the different stages via a profitability analysis. Secondly, a value chain analysis requires additionally the mapping of the major constraints within the opportunities and the institutional environment of each actor to identify the options to upgrade the value chain network.

Agricultural Value Chains and Food Security

The agricultural value chain normally refers to the entire range of goods and services required for an agricultural product to move from the farm to the final customer. An agricultural value chain may include: input supply, farmer organization, farm production, post-harvest handling, processing, provision of technologies and handling, grading, cooling and packing, post-harvest local processing, industrial processing, storage, transport, finance, and feedback from markets.

Development of agricultural sector has a strong impact on reducing poverty and enhancing food security. Organization of agriculture along the value-chain framework is one of the ways to realize the full potential of this sector (Kumar et al., 2011). According to World Food Summit (1996), food security is defined as “when all people at all times have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preference for an active and healthy life”. Food insecurity including malnutrition is both a cause and a result of poverty. Therefore, value chain projects aiming to poverty reduction cannot ignore food security. The integration of the value chain approach and food security is presented in terms of three recognized dimensions of food security: 1) consistent availability of appropriate food from domestic production and commercial imports or donors; 2) individual access to appropriate food from expending income or other resources; 3) proper utilization of food, adequate knowledge and application of nutrition and child care techniques, and adequate health and sanitation services.

All these three aspects are important for food security and are linked. Food availability is necessary but not sufficient for food access. Again, food access is necessary but not sufficient for effective food utilization. Figure 1.8 clearly illustrates the different activities corresponding actors that are needed to achieve and enhance the concepts of food availability, food affordability, food acceptability and food quality. There are also several alternative approaches to agricultural development that are used to encourage poor groups of people to be part of more modern value chains. These approaches want to increase the return to the farmers by means of improving processes, products, functions, volume and coordination (Hawkes and Ruel, 2012). Value chain concepts have the potential to influence both the supply and the demand of nutritious foods such as rice. The analysis gives an indication of the availability, the price and the quality of the foods together with the interference of the government.

Dixit (2014) stated that a value chain perspective on the agricultural sector delivers guidelines to address certain constraints and restrictions related to the development of the agricultural sector and the realization of food security objectives. Due to the increasing globalization and the increased acquisition and distribution channels, research of the value chains is becoming more important in agriculture. Dixit (2014) also stated that a value chain-based policy framework can facilitate food security considerations and also mentions ‘food availability on the national market’, ‘food accessibility for people’ and ‘food utilization’ as the core aspects of assuring food security.

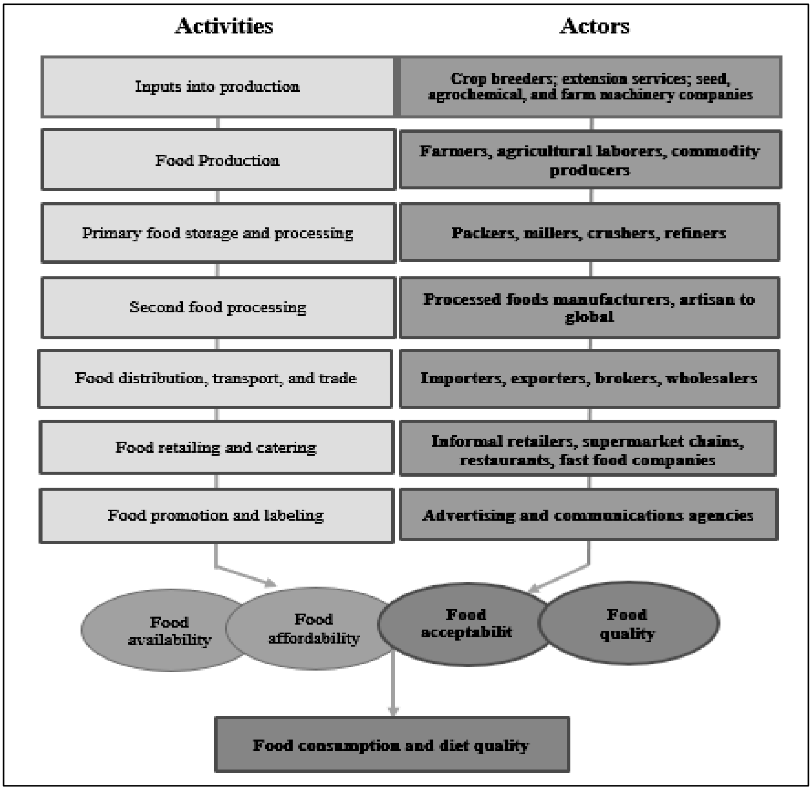


Figure 1.8 A simplified representation of a food supply chain
Source: Hawkes and Ruel (2012)

1.2.2 Uncertainty in the agricultural supply chain

Uncertainty can be described as the inability to predict something (Milliken, 1987). According to Knight (1971), if it is not possible to quantify a probability of occurrence, it is called uncertainty. Simangunson, et al. (2012) stated that when considering the consequences of uncertainty, if they are positive, they are called chances and if they may be negative, then they are risks. In addition, according to Wang et al. (2014), managers have to face and manage both supply chain uncertainty in a real environment in the world. Moreover, since the processes involve various organizations in the supply chain network, uncertainty cannot be avoided for a finished product. According to Miller (1993), uncertainty refers to '*the unpredictability of environmental or organizational variables that have an impact on corporate performance*'.

Agricultural food supply chain has unique characteristics with sources of uncertainty factors which are different from those of other supply chains. Many sources of uncertainty for food supply chains appear due to variable harvests and production yields, perishability of products and the huge impact of weather conditions on production and customer demand (Jack and Adrie, 2002). Based on the studies of Badri et al., (2000), van der Vorst (2000), Li (2002), Paulraj & Chen (2007) and Thongrattana (2012), the seven uncertainty factors are considered in this study. The details of each uncertainty factor are as follows:

Supply Uncertainty: Supply uncertainty is related to unpredictable and uncontrollable factors in material supply. Supply uncertainty is defined as the degree of exchange and unpredictability of the design of suppliers, quality and delivery performance. Uncertainty caused by suppliers, such as late delivery, machine broken, quality of incoming material or parts, and degree of inconsistency will postpone or delay a manufacturing process. Geary et al. (2002) considered supply chain uncertainty as the results from poorly performing suppliers not meeting organization's needs. Li (2002) assessed supply uncertainty by providing factors such as unpredictability of engineering level, product quality, delivery time and quantity.

Demand Uncertainty: The variation in customer demand is one source of supply chain uncertainty. Customer uncertainty is defined as the extent of change and unpredictability of the needs and demands of customers (Zhang et al., 2002). Geary et al. (2002) stated that customer uncertainty can be viewed as the difference between the actual end-marketplace demand and the orders placed with an organization by its customers. It can be measured in terms of how well companies meet customer demand. Moreover, customer uncertainty can be defined as the link to the predictability of the demand for the product. Customer uncertainty involves unknowns associated with product characteristics or environmental factors and causes difficulties in predicting and controlling the demand for a final product.

Process Uncertainty or Manufacturing Uncertainty: Problem with manufacturing process is another source of supply chain uncertainty which is related to unpredictable and uncontrollable factors in the manufacturing process. Process uncertainty can be caused by a production stop as a result of a machine breakdown, process disorder due to a computer crash, or a production bottleneck because of improper workflow design (Davis, 1993).

Planning and Control Uncertainty: It is related to the planning and communication structure needed to provide correct and on-time information about inventory level, production capacity and customer orders (van der Vorst, 2000). Information is crucial to operational control for planning and management: the higher the quality of information input, the higher the quality of managerial decision-making (Gorry & Morton, 1989). Poor control systems i.e. incomplete information or wrong decision rules introduce uncertainty into the supply chain (Childerhouse & Towill, 2004).

Competitor Uncertainty: The unpredictability of competitor actions such as reducing the price of products is referred to competitor uncertainty (Li, 2002). In any organization, the competitor is one external factor which can introduce perceived uncertainty into organizations (Duncan, 1972). Competitor uncertainty is defined as the extent and unpredictability of the competitors' actions (Li, 2002). Globalization and demanding customers increase the level of competency in business. Organizations that focus on domestic markets must be able to understand foreign rivals that penetrate their markets. As a result, firms have no choice but to develop global perspective of competition by recognizing the entry of new competitors and the necessity of partnership with other organizations. This competition is forcing firms to rearrange their business strategies away from conventional, cost-based strategies to knowing which feature a customer wants.

Government Policy Uncertainty: Laws, regulations, administrative procedures and policies formally sanctioned by the government and which impact on a firm's profitability by altering its costs and revenues, introduces government policy uncertainty into the supply chain (Badri et al, 2000). Government regulation can provide both risks and benefits to business in many ways, but unpredictable government policy can forces business decision-makers to take risks in investment, especially in new technology (Marcus, 1981).

Climate Uncertainty: Climate uncertainty refers to the unpredictability of serious weather events such as drought, flooding and temperature which can lead to decreased rice yield, rice supply shock, and delay delivery time to market or transportation disruption (Curz et al, 2007). According to Darwin et al. (1995), climate is a major factor directly and indirectly affecting most agricultural and socio-economic systems associated with land-use planning, agricultural yield level, agricultural infrastructure, etc. especially in developing countries where the agricultural system is mostly dependent on rainfall and there is a lack of technological adaptations.

1.2.3 Agricultural supply chain performance

The supply chain is defined as "all of the activities associated with moving goods from the raw materials stage through to the end user. This includes sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer services. Importantly, it also embodies the information systems so necessary to monitor all of those activities" (Quinn, 1997). These efforts require management and therefore management of these supply chains is important. The purpose of the supply chain management is to achieve the improved long-term performance of the individual companies and the supply chain as a whole. This result in such benefits as reduced operation costs, increased market share and sales and solid customer relations (Mentzer et al., 2001)

Supply chain performance on the other hand ensures efficiency in providing goods as per market demand and thus the need for measuring performance as there exists interdependence among supply chain partners which is important for survival and prosperity of a firm. Supply chain performance is defined as the operational excellence to deliver leading customer experience (Simchi-Levi, 2003).

The aim of any agri-food supply chain is to achieve a full and effective flow of goods, services and information, transferring capital to create and provide maximum customer value. Regardless of the organizational form of each agri-food supply chain the companies could choose one of the following way as a developing strategy: strategic planning of acquisitions, labour productivity growth, increased financial result and improving the efficiency of distribution. In order to measure the performance of agri-food supply chain is needed to permanently update information regarding the performance of suppliers and customers (Burgess et al., 2006), knowledge of their marketing strategies, and continuous analysis and updating component costs logistics, such as domestic and international transport, customs, storage, packaging or repackaging and special physical distribution of finished products (Dinu, 2016). Therefore, the correct communication in the supply chain between chain partners, but also within the participating companies and the accuracy of the information circulating on both the vertical and the horizontal line are key factors with major influence in the performance of this flow of information, goods and services.

1.3 Chapter Overview and Contributions

In the last introductory section, we provide a short summary of the studies presented in the different chapters of this dissertation. Each of the chapters (apart from the conclusion chapter) corresponds to an original academic paper. The link between the different chapters and the papers is presented in this section. Although the different chapters are self-contained academic studies, and the references for all chapters will be expressed in the last section of this book. Chapter 2 to 4 are three different studies of this dissertation and this book is concluded in Chapter 5. These three studies (cf. Figure 1.9) were designed to contribute to the academic literature by answering the following research questions, i.e.:

General research question: How can the value chain of the rice industry be developed to improve **food security and reduce rural poverty in Myanmar?**

Seventy percent of the rural population of Myanmar engages in rice farming for their livelihood (MOAI, 2015b). The value chain development can improve the living conditions of the rural population (i.e. poverty reduction) and contribute to food security (EuropeAid, 2011). In the rice value chain development, there are different challenges and strategic objectives in the rice sector in Myanmar. Moreover, the main challenge considered here is "increasing the performance and sustainability of the rice industry may improve the food security and reduce poverty in the country". This dissertation is compiled in consideration of these challenges and strategic objectives and aims to provide some possible solutions for promoting food security and rural poverty reduction in Myanmar with the perspective of the operational analysis of the rice value chain.

In order to solve the general research question, three different studies are undertaken to investigate the following research questions. The relationship between these different studies is presented in Figure 1.9.

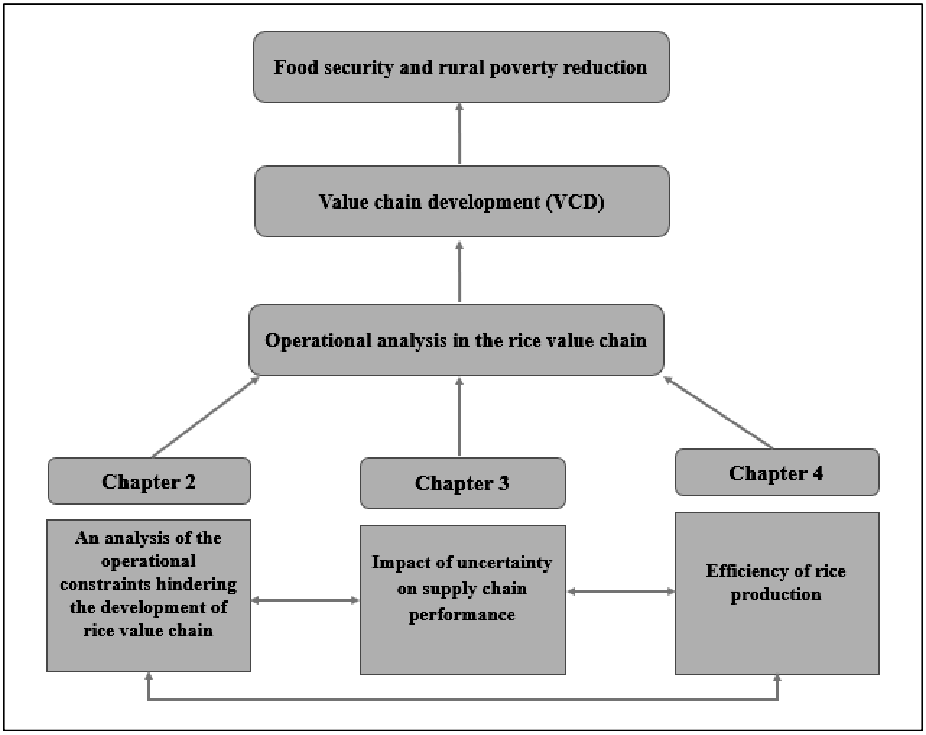


Figure 1.9 The link among three different studies

RQ1 What are the operational constraints hindering the development of the rice value chain in Myanmar and what are the solutions to these bottlenecks of the rice value chain?

Chapter 2 presents the paper entitled "*An analysis of the operational constraints hindering the development of the rice value chain in the Ayeyarwaddy Region, Myanmar*". In this chapter, firstly, we map the structure of the rice value chain in order to know clearly which actors involve in the chain in the Ayeyarwaddy Region, Myanmar. We calculate the financial data to obtain the costs of production and marketing of different actors and then we estimate the profits of these actors by employing marketing cost and margin analysis. This analysis identifies the distribution of marketing costs, margins and profits along the actors in the rice value chain. Secondly, by applying the descriptive and inferential statistics, the socio-demographic characteristics and operational constraints of the different actors are described to know the status and challenges of the different actors in the rice value chain. Lastly, we link these identified socio-demographic characteristics and operational constraints to the profitability of the different actors. Moreover, we map the operational constraints faced by the actors along the rice value chain and discuss the interventions of the governments cooperating with the private sectors to develop the rice value chain in the study area.

RQ2 Which uncertain factors influence the rice supply chain performance in Myanmar?

Chapter 3 presents the results of the paper entitled "*The impact of uncertainty on the performance of the rice supply chain in the Ayeyarwaddy Region, Myanmar*". This chapter emphasizes the relationship between the uncertainty and supply chain performance of different actors and global rice supply chain in the Ayeyarwaddy Region, Myanmar. First, we use the descriptive statistics and factor analysis to study the sources of uncertainty and the most important uncertainty factors perceived by the different actors in the rice supply chain, respectively. Second, we measure the rice supply chain efficiency as a measurement of supply chain performance. We apply the input-oriented DEA approach to evaluate the efficiency of rice production stage, processing stage, distribution stage and finally global rice supply chain. We consider the marketed amount of paddy and rice as the output variable and the costs of production, financial, transportation and storage as the input variables. Third, a Tobit regression analysis is used to determine the influence of uncertainty factors on the supply chain efficiency in these three different stages and the global rice supply chain. We use the seven uncertainty factors discussed in Section 1.2.2 as the independent variables and the technical efficiency as the dependent variable in the Tobit model.

RQ3 How to improve the efficiency of the paddy production in Myanmar?

Chapter 4 presents the results of the paper entitled "*The efficiency of the rice production of the farmers in the Ayeyarwaddy Region, Myanmar*". First, we employ the input-oriented DEA approach to estimate the overall technical, pure technical, scale, allocative and economic efficiency of the rice farmers in the Ayeyarwaddy Region. We consider the paddy yield as the output variable and the amount and price of the seed, urea fertilizer, herbicide, animal power, machine power and human labor. We determine the farmer and industry characteristics factors that impact the efficieny of the rice farmers by using a Tobit regression analysis. The dependent variables are all different efficiencies considered in this study and the independent variables involve the age, education and experience (farm-farmer related variables), the variety used (farm-production related variable) and the extension services received by the farmers (farm-institution related variable).

The answers to these research questions provide the following contributions to the academic literature, i.e.

- The contribution of Chapter 2 is threefold. Firstly, we estimate the marketing costs and margins to evaluate the profits of the different actors involved in the rice value chain. Secondly, we study the operational constraints of the different actors in the rice value chain. Lastly, via a regression analysis, we relate these operational constraints to the profitability of an actor to detect the significant and most important constraints. Based on this analysis, options are identified to upgrade the value chain network in the Ayeyarwaddy Region, Myanmar.

- Chapter 3 contributes threefold to this dissertation. First, we identify the sources of uncertainty perceived by the different actors in the rice supply chain in the Ayeyarwaddy Region, Myanmar. Second, we measure the rice supply chain efficiency to assess the supply chain performance. Finally, we study the impact of uncertainty on supply chain efficiency to understand the challenges of the supply chain the region is dealing with and to identify solutions to improve the supply chain operations.

- Chapter 4 emphasizes the efficiency of the rice production of the farmers and contributes threefold. First, we estimate the overall technical, pure technical, scale, allocative and economic efficiency of the rice farmers in the Ayeyarwaddy Region. Second, we determine the influencing factors on these different efficiencies of the rice farmers. Finally, results of this study provide relevant recommendations for the farmers to better control the resource usage and improve the operational decision-making in the rice production especially for rural development and food security in Myanmar. Moreover, the challenges of inadequate infrastructure, weak extension and education system, volatility of paddy price that contributes to low farmer incomes and policies that hamper investments in the rural and rice sector can be realized from this chapter.

In Chapter 5, we reflect on the studies of Chapter 2 through 4. While each chapter contains a separate conclusion, this final chapter closes with more general remarks than the specifics found in each chapter. The conclusion constitutes the finale of this dissertation and looks back on the work we have done throughout these years of research. We also provide a future outlook and discern limitations of the study and future research directions.

Acknowledgements

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Unpublished working papers

- Linn, T. and Maenhout, B. (2018). An analysis of the operational constraints hindering the development of the rice value chain in the Ayeyarwaddy Region, Myanmar. *Under revision in Asian Journal of Agriculture and Development (Accepted for publication).*
- Linn, T. and Maenhout, B. (2018). The Impact of uncertainty on the performance of the rice supply chain in the Ayeyarwaddy Region, Myanmar. *Under review in Agriculture and Food Economics (Second round).*
- Linn, T. and Maenhout, B. (2018). Measuring the efficiency of the rice production in Myanmar using Data Envelopment Analysis: A non-parametric approach. *Under review in Asian Journal of Agriculture and Development (First round).*

1.A Appendix: The position of Myanmar among the rice producing countries in Asia

This part illustrates the position of rice producing countries in Asia. The following tables show the degree of development of a country by means of the Human Development Index (HDI) and its components. Myanmar remains one of the poorest countries in the world with poverty in rural areas significantly higher than in urban areas. A large segment of the population is highly vulnerable to adverse weather and experiences periodic bouts of impoverishment. The top 10 rice producing countries in the world today are India, China, Indonesia, Bangladesh, Thailand, Vietnam, Burma (Myanmar), the Philippines, Cambodia, and Pakistan and all of the top rice exporting countries are in Asia. But, we will point out the position of Myanmar relative to the other neighbouring top rice exporting countries such as India, China, Bangladesh and Thailand. Myanmar is the poorest country compared to the other top rice producing neighbouring countries according to the following evidences. The following tables show the degree of development of a country by means of the Human Development Index (HDI) and its components. The data were accessed from various sources.

1.A.1 Human Development Index: Components and Trends

Definitions

Table 1.A.1 depicts multiple facets that represent the development of countries:

Human Development Index: A composite index that measures the average achievement in three basic dimensions of human development: A long and healthy life, knowledge and a decent standard of living.

Life expectancy at birth: Numbers of years a new born infant could expect to live if prevailing patterns of age-specific mortality rates at the time of birth stay the same throughout the infant's life.

Expected years of schooling: Numbers of years of schooling that a child of school entrance age can expect to receive if prevailing patterns of age-specific enrolment rates persist throughout the child's life.

Mean years of schooling: Average number of years of education received by people ages 25 and older, converted from education attainment levels using official durations of each level.

Gross National Income (GNI) per capita: Aggregate income of an economy generated by its production and its ownership of factors of production, less the incomes paid for the use of factors of production owned by the rest of the world, converted to international dollars using PPP (Purchasing Power Parity) rates, divided by midyear population.

Interpretation

We can divide the development status of the countries based on their Human Development Index (HDI). According the classification of HDI, Thailand and China are included in very high human development group within the HDI index of 0.700-0.799, and India, Bangladesh and Myanmar are standing as the medium human development group within the HDI index of 0.550-0.699. From Table 1.A.1, we can conclude that Myanmar's life expectancy, education and development is lower than those of other neighbouring top rice producing countries. Even though Gross National Income per capita of Myanmar is a bit higher than Bangladesh among the medium human development countries, other indicators for human development are lower than Bangladesh.

Moreover, the evolution of HDI for different years is depicted in Table 1.A.2, as well as the average growth of HDI over time. The average annual HDI growth is the smoothed annualized growth of the HDI in a given period, calculated as the annual compound growth rate. It is clear that the HDI for Myanmar is significantly lower than those of Thailand and China and a slightly lower compared to India and Bangladesh over the years. From the period of 1990 to 2015, even though the average annual HDI growth rate was the highest, the HDI for every year were the lowest among other countries.

Table 1.A.1 Human Development Index and its components in 2015

Sr. No.	Country	Human Development Index (HDI)(value)	Life Expectancy at birth (years)	Expected years of schooling (years)	Mean years of schooling (years)	Gross National Income (GNI) per capita (2011 ppp $)
	High Human Development Countries (0.700 - 0.799)					
1	Thailand	0.740	74.6	13.6	7.9	14519
2	China	0.738	76.0	13.5	7.6	13345
	Medium Human Development (0.550 - 0.699)					
3	India	0.624	68.3	11.7	6.3	5663
4	Bangladesh	0.579	72.0	10.2	5.2	3341
5	Myanmar	0.556	66.1	9.1	4.7	4943

Source: UNDP (2016)

Table 1.A.2 Human Development Index for 1990-2015 and the average annual HDI growth per country for this period

Sr. No.	Country	Human Development Index (HDI) (value)								Average Annual HDI growth (%)			
		1990	2000	2010	2011	2012	2013	2014	2015	1990-2000	2000-2010	2010-2015	1990-2015
	High Human Development												
1	Thailand	0.574	0.649	0.720	0.729	0.733	0.737	0.738	0.740	1.25	1.03	0.56	1.02
2	China	0.499	0.592	0.700	0.703	0.713	0.723	0.734	0.738	1.72	1.7	1.05	1.57
	Medium Human Development												
3	India	0.428	0.494	0.580	0.590	0.599	0.607	0.615	0.624	1.45	1.62	1.46	1.52
4	Bangladesh	0.386	0.468	0.545	0.557	0.565	0.570	0.575	0.579	1.95	1.54	1.21	1.64
5	Myanmar	0.353	0.427	0.526	0.533	0.540	0.547	0.552	0.556	1.9	2.12	1.1	1.83

Source: UNDP (2016)

1.A.2 Poverty in Myanmar

Definition

Table 1.A.3 shows the population below the national poverty line of Myanmar relative to the top rice producing neighbouring countries: national estimates of the percentage of the population falling below the poverty line are based on surveys of sub-groups, with the results weighted by the number of people in each group. Definitions of poverty vary considerably among nations. For example, rich nations generally employ more generous standards of poverty than poor nations.

The poverty in Myanmar is also illustrated by the Table 1.A.4, which depicts the population trends, mortality rates and literacy rate. Table 1.A.4 has included the following characteristics statistics:

Total population: De facto population in a country.
Population growth rate: The average annual percent change in the population, resulting from a surplus (or deficit) of births over deaths and the balance of migrants entering and leaving a country.
Median age: Age that divides the population distribution into two equal parts – that is, 50 percent of the population is above that age and 50% is below it.
Adult mortality rate: Probability that a 15-year-old will die before reaching the age of 60, expressed per 1000 people.
Adult literacy rate: Percentage of the population ages 15 and older who can, with understanding, both read and write a short simple statement on their everyday life.

Table 1.A.5 consists of the following variables**:**

Gross Domestic Product (GDP) - per capita (PPP): This entry shows GDP on a purchasing power parity basis divided by population as of 1 July for the same year.
Labour force participation rate: Percentage of a country's working-age population that engages actively in the labour market, either by working or looking for work. It provides an indication of the relative size of the supply of labour available to engage in the production of goods and services.
Unemployment rate: This entry contains the percent of the labour force that is without jobs. Substantial underemployment might be noted.

Youth unemployment rate: Percentage of the labour force population ages 15-24 that is not in paid employment or self-employed but is available for work and has taken steps to seek paid employment or self-employment.

Interpretation

According to Table 1.A.3, Myanmar had higher percentage in population (25.6%) below the national poverty line compared to other neighbouring rice producing countries except from Bangladesh (31.5%) in 2015. From Table 1.A.4, we can see that the population growth became decreasing during 1960 to 2016 in all countries. However, the population is also expected to keep increasing. It is clear that the median ages of the population in Thailand and China are significantly higher than those of the Medium Development countries including Myanmar. This is yet another indicator of the poor conditions in which people of Myanmar have to live. Thereby, the adult mortality rates in female (173 per 1000 people) and male (229 per 1000 people) were the highest in Myanmar in 2014 relative to other rice producing neighbouring countries. According to the data presented in the table, the adult literacy rate of Myanmar was higher than India and Bangladesh and lower than Thailand and China in 2015. However, obviously, poverty goes together with the restrictions in terms of education. As we can derive from the table, the percentage of population with at least some secondary education (% ages 25 and older) was the significantly lowest in Myanmar (23.8%) compared to other rice producing neighbouring countries in 2015.

The GDP per capita gives a better representation than the total GDP because it is taken relatively to the population. The GDP per capita is an also an indication of the poverty in Myanmar. According to Table 1.A.5, the GDP per capita PPP was the significantly lower in Myanmar (1700 $) than other neighbouring countries. Employment rate or labour force participation rate and unemployment rate are used as the indicators of the poverty of the country. Even though the employment rate of Myanmar was the highest among the countries mentioned in the table, the unemployment rate in total population was the highest in Myanmar (4.7%) in 2015. As in the case of youth unemployment rate was also the higher in Myanmar (12.1%) than other countries except from China (also 12.1%).

Table 1.A.3 Percentage of population below the national poverty line in 2015

Sr. No.	Country	Population below national poverty line (percentage)
	High Human Development	
1	Thailand	10.5
2	China	3.3
	Medium Human Development	
3	India	21.9
4	Bangladesh	31.5
5	Myanmar	25.6

Source: World Factbook (2017)

Table 1.A.4 Population trends, mortality rates and literacy rate for top rice producing countries

Sr. No.	Country	Total Population in millions		Population growth rate (2014)		Median age (years)	Adult mortality rate (female per 1000 people)	Adult mortality rate (male per 1000 people)	Adult literacy rate in 2015 (% ages 15 and older)	Population with at least some secondary education (% ages 25 and older)
		1960	2016	1960	2016	(2015)	(2014)	(2014)	(2015)	(2015)
	High Human Development									
1	Thailand	27.4	68.9	3	0.3	38	105	207	96.7	43.3
2	China	667.1	1378.7	1.8	0.5	37	72	98	96.4	75
	Medium Human Development									
3	India	449.5	1324.2	1.9	1.1	26.6	145	217	72.1	48.7
4	Bangladesh	48.2	162.6	2.8	1.1	25.6	107	152	61.5	43.1
5	Myanmar	20.9	52.9	2.1	0.9	27.9	173	229	93.1	23.8

Source: UNDP (2016)

Table 1.A.5 National Income in 2013 and Employment rates in Myanmar relative to the other neighboring top rice producing countries in 2015

Sr. No.	Country	Gross Domestic Product (GDP per capita PPP $)	Employment rate to population ratio (% ages 15 and older)	Unemployment	
				Unemployment rate in total population (%)	Unemployment rate of youth (%)
	High Human Development				
1	Thailand	9900	70.6	1.1	4.7
2	China	9800	67.6	4.6	12.1
	Medium Human Development				
3	India	4000	51.9	3.5	9.7
4	Bangladesh	2100	59.4	4.4	11.6
5	Myanmar	1700	74.3	4.7	12.1

Source: UNDP (2016)

2

An Analysis of the Operational Constraints Hindering the Development of Rice Value Chain in the Ayeyarwaddy Region, Myanmar

The rice industry is the most important agricultural subsector in Myanmar. However, compared to other ASEAN countries, far lower profits are gained from producing rice. This paper analyzes the operational constraints of the rice value chain in Myanmar for the different actors in the rice value chain. Both primary and secondary data are collected for the rice value chain in the Ayeyarwaddy Region, which is the main rice growing area in Myanmar. The actors suffer especially from material input constraints, production constraints, financial constraints and distributional and institutional constraints. In order to provide proper policy guidelines, the profitability of the actors, together with their social-demographic and operational characteristics are examined. It was found that the value chain in the study area is structured in an inefficient manner, characterized by a large number of actors that face a large number of constraints. Based upon our analysis, different policy recommendations are put forward to upgrade the rice value chain in the Ayeyarwaddy Region of Myanmar.

In this perspective, the stakeholders should be encouraged to undertake different actions to increase the quantity and quality of rice produced, ranging from input quality control and more efficient extension services. In addition, credit and sufficient working capital should be provided to make infrastructure investments possible in different stages of the value chain to increase rice production and profitability significantly.

2.1 Introduction

Agriculture plays a major role in Myanmar by ensuring food security as well as in the provision of employment and income for a growing population. In 2014-2015, 22.1 % of the GDP resulted from agriculture (MOAI, 2015a). The rice industry is the most important agricultural subsector in the country, accounting for about half of the cultivated land. In 2016, the paddy production in Myanmar was ranked 7th of the paddy producing countries in the world (World Rice Production, 2017). According to MOALI (2016), paddy has the highest percentage share 46% among crops grown in Myanmar. In addition, most of the household income is earned from rice farming and related activities. In 2013-2014, the net profit averaged \$114/ha for producing monsoon paddy. However, these farm profits in general are not sufficient to raise households' per capita income above the regional rural poverty line (Zorya, 2016). Zorya (2016) reported that in Myanmar far lower profits are gained from producing rice compared to other countries in Asia. This indicates that the potential of the agricultural sector has not yet been realized when it comes to poverty reduction.

The value chain development is an approach to reduce the rural poverty and has been adopted by governments and NGOs (World Bank, 2014). In this paper, the rice value chain in the Ayeyarwaddy Region of Myanmar is analyzed. The issues in this region are complex and multifaceted. There is a lack of information on the coordination and interaction between actors of the same stage (horizontal cooperation) and of different stages in the supply chain (vertical cooperation) since the linkages and relationships among the actors are fragmented. In particular, the constraints of the rice value chain in the Ayeyarwaddy Region are studied in order to identify the main bottlenecks. This paper follows the framework of Trienekens (2011) and starts from the network structure of the rice value chain to examine (1) the socio-demographic characteristics of the actors in the chain and the value addition in the different stages via a profitability analysis; (2) the major constraints that limit the operations of each actor. These operational constraints are related via a regression analysis to the profitability of an actor to detect the significant and most important constraints. In this way, options are identified to upgrade the value chain network in the Ayeyarwaddy Region of Myanmar.

The remainder of the paper is organized as follows. Section 2.2 provides a review on the relevant literature. The methodology concerning the empirical data collection and data analysis is described in Section 2.3. Section 2.4 discusses the findings for the study area. A discussion of the findings and ways to upgrade the value chain is provided in Section 2.5. The conclusion and policy recommendations are summarized in Section 2.6.

2.2 Literature Review

The idea of the value chain is based on the process view of an organization or a supply chain (Porter, 1985). A value chain describes the product transformation and value adding activities with inputs, transformation processes and outputs in each stage of the chain to bring a product through different stages of production, distribution, marketing to consumer delivery, i.e. the value chain structure (Kaplinsky and Morris, 2001). The value chain activities require the acquisition and consumption of resources (e.g. money, labor, material) and determine costs and profits of each actor participating in the supply chain network. The methodology has been applied to understand commodity chains and export strategies especially in developing countries (Kaplinsky and Morris, 2001). According to Trienekens (2011), a value chain analysis requires additionally the mapping of the major constraints within the opportunities and the institutional environment of each actor to identify the options to upgrade the value chain network.

Constraints imposed on the development of a value chain are related to market access, market knowledge and orientation, the available resources and infrastructure and institutions. Market access is dependent on the technological capabilities of producers, available infrastructures, bargaining power and market knowledge and orientation. Market knowledge and orientation refers to the intelligent capturing of consumers' needs and using this knowledge to increase the added value of activities to upgrade the value chain (Grunert et al., 2005). However, constraints on resources and infrastructure (e.g. lack of specialized skills and difficult access to technology, inputs, market information, credit and external services) may obstruct this upgrade (Giuliano et al., 2005). The value chain in developing countries can be characterized as a local low-income chain. Producers are usually small with traditional production systems. These chains include many intermediary parties and are relatively long. This implies that the availability of market information is limited, the added value is distributed over a large number of actors and transportation and distribution problems are more profound (Trienekens, 2011). Furthermore, upgrading can be hindered as a result of government legislation, regulations and policies by e.g. setting trade barriers for production technology, limiting the flow of information, denying infrastructural investments. According to Marti and Mair (2008) developing countries are often characterized by institutional voids, where institutional policies and regulations are absent, weak or fail to accomplish their role. A facilitating government that supports innovation and upgrading is often considered conditional for development (e.g. Murphy, 2007). In the following, this paper reviews the relevant studies on the value chain analysis in the rice industry in Asian countries (Section 2.2.1) and the rice value chain in Myanmar (Section 2.2.2).

2.2.1 Rice value chains in some ASEAN countries

In the literature, different studies reported on the value chain of the rice sector in ASEAN countries. Especially in the low-income countries, i.e. Cambodia, Lao PDR and Myanmar, the rice industry is the crucial agricultural subsector and is important in terms of land use, farm income and food consumption. Improving the rice sector performance and developing the value chain is critical to reduce poverty in these three countries (World Bank, 2014). Compared to the neighboring countries Thailand and Vietnam, the rice value chains of Cambodia, Lao PDR and Myanmar are characterized by less efficient input supply systems, a lower farm productivity and profitability, higher milling and export costs and a lower quality of exported rice (Zorya et al., 2016). As a result, the rice value chains in Cambodia, Lao PDR and Myanmar are less competitive than those in Thailand and Vietnam, which is detrimental in the international market as all these countries are net rice exporters, and these countries have much lower export volumes. In addition, the profits of the individual actors in the value chain in these countries are lower caused by lower yields, lower output prices and higher production costs making them more vulnerable.

Zorya et al. (2016) claimed that improvements are required at all stages of the value chain in all three countries. In the production phase, farmers should increase the productivity and quality of paddy produced in a sustainable manner, particularly due to constraints with respect to the availability of good-quality seeds and the lack of quality extension services. The rice mills to process the paddy to rice should lower their costs by improving the process efficiency and quality and increasing the processing capacity. In these countries, there are many rice mills in operation. Many of them are (too) small dealing with capital shortage problems and a very severe competition. In the distribution phase, the export of the country of Myanmar relies too heavily on cross-border trade and other countries should be exploited to increase the rice export profitability. In recent years, Cambodia has made the most progress in the production, milling, and export segments whereas Myanmar is lagging behind.

2.2.2 Rice value chain in Myanmar

The rice value chain of Myanmar has been studied by Wong and Wai (2013). This study mapped the overall rice supply chain by investigating the structure, performance and economics of rice production, marketing and trading. The authors recommended to increase efficiency, raise productivity, reduce risk and encourage private investments along the rice supply chain. The structure of the rice value chain in the study area is shown in Figure 2.1, which has been validated at the start of this study. The rice value chain starts from the supply of inputs (agrochemicals, machinery, seeds, credit and extension services) to farmers for the paddy production. The cultivation of paddy requires different activities such as preparing the land, sowing seeds, transplanting seedlings weeding, applying fertilizers and pesticides, harvesting, threshing, drying, winnowing, storage and selling the surplus after allowing for home consumption. Primary collectors buy the paddy from the farmers with the financial support of millers. The millers give fees to the primary collectors and mill the paddy to rice. They carry out different activities that add value such as transportation, processing, grading and packing. The millers store and distribute rice mainly to wholesalers. Wholesalers deliver rice on their turn to retailers in order to supply the domestic consumers or to exporters who supply consumers in foreign countries.

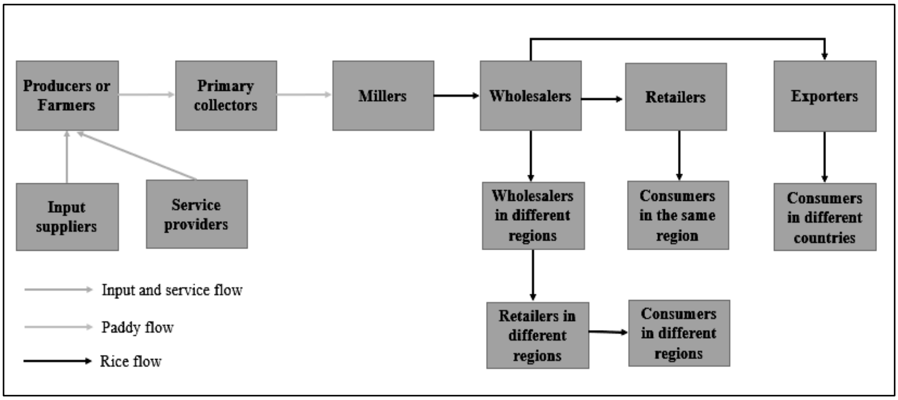

Figure 2.1 Structure of the rice value chain in the study area
Source: Own survey (2017)

A study issued by the Ministry of Agriculture and Irrigation (MAOI, 2015b) posed that the rice value chain in Myanmar is not well integrated and its efficiency should be improved. There are (too) many different actors in the different stages and (too) many stages ranging from individual farmers to large scale wholesalers and exporters. The chain is characterized by several weaknesses at various stages in the chain, which causes high transaction costs for all actors (World Bank, 2014; Raitzer et al., 2015; MOAI, 2015b). The farmers in Myanmar have to deal with inputs of low quality, i.e. inferior input seeds, poor water management, inferior quality of chemical fertilizers and inappropriate use of pesticides and herbicides, which are viewed as reasons for their low yield. In addition, they face seasonal labor shortages and a lack of credit to upgrade their operations. The infrastructure of most millers, i.e. the milling machines and power supply, is outdated, costly and unreliable leading to an inferior rice quality, which does not meet the standards for export. Moreover, the investments efforts in the rice industry, which are currently mainly done by the government, are insufficient with respect to (1) the infrastructure (such as multi-purpose dams, irrigation and drainage canals, farm roads); (2) the agricultural support services, i.e. research, extension and credit (currently 100,000MMK per acre with 0.045% interest rate (San, 2017)). As a result, all actors in the supply chain encounter a lack of capital to invest in the production, processing and distribution facilities (World Bank, 2014; Raitzer et al., 2015).

2.3 Research Methodology

2.3.1 Data collection and sampling technique

Both primary and secondary data are collected for the rice value chain in the Ayeyarwaddy Region, which is the main rice growing area in Myanmar. This study is conducted in two selected townships, Myanaung and Kyangin, in the Ayeyarwaddy Region (cf. Appendix Figure 2.A.1). These two townships are two of rice special areas especially Emata rice group in Myanmar for the local area which are rice deficit such as Pakokku, Aung Lan, Magwe, Tha Yet and Mindon in Magway region. Emata rice is also mostly exported to other countries. The purposive and stratified random sampling method is used to collect primary data. As a cross-sectional survey, in-depth and key informant interviews are used to interview sample respondents (Umberger, 2014). The stratification of the population is based on their role in the supply chain. For each subpopulation, a random sampling method is applied to form a test group. The sample size is calculated for each stratum in direct proportion[1] to the size of the stratum compared to the (finite) population (cf. Appendix 2.A.1) (Judez, 2006). As a result, a sample of 130 farmers, 21 primary collectors, 25 millers, 7 wholesalers, 28 retailers and 4 exporters is selected for conducting the face-to-face interviews.

The primary data includes the socio-economic characteristics of the value chain actors, financial information about sales volumes and prices, transaction costs and constraint information. The constraint information is gathered via a binary response questionnaire. The secondary data is collected from the Department of Agriculture (DOA), Ministry of Agriculture, Livestock and Irrigation (MOALI), Myanmar Rice Federation (MRF), FAOSTAT, websites and other relevant data sources.

2.3.2 Data analysis method: Socio-demographic, financial and constraint information

Descriptive statistics (mean, frequency, percentage and range) are applied using SPSS to describe the characteristics of the value chain, i.e. socio-economic and constraint data of the sample respondents, based on the cross-sectional data obtained from the survey. Inferential statistics are used to describe and make inferences, to apply hypothesis testing and identify significant differences between groups of actors in the value chain. Moreover, the *concept of enterprise budget* (Olson, 2009) is used to evaluate the profitability of the actors. This enables us to evaluate the cost and return of the value adding activities. The return above variable cost or the gross margin is calculated as follows

$$\text{Return above variable cost (RAVC)} = \text{Total Gross Benefit} - \text{Total Variable Cost} \quad (2.1)$$

The total variable cost takes material costs, hired labor costs, family labor cost and the interest on cash cost into account.

Furthermore, we determine the marketing costs, the marketing margins and the marketing profits of the different actors in the value chain via *a marketing cost and margin analysis*, which has been applied by Raha and Akbar (2010), Abdullah et al. (2015) and Miah (2013)

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[1] This is based on the equation of Yamane (1967), i.e. $n = \frac{N}{1+N(e^2)}$ where N is the population, e^2 is the standard error and n is the sample size.

amongst others. The difference between the price of any product at one stage in the marketing process and the price of the equivalent product at another stage of marketing is called the marketing margin (Smith, 1992), i.e.

Gross marketing margin (GMM) = Selling price – Purchase price paid by an actor *(2.2)*

Total gross marketing margin (TGMM) = Consumer price – Producer price *(2.3)*

The net marketing margin (NMM) or marketing profit is the percentage over the final price earned by the middleman as his or her income after deducting his or her marketing costs. The net marketing margin can be calculated as follows

Net Marketing Margin (NMM) = (GMM – Marketing cost)/Consumer price x 100 *(2.4)*

2.3.3 Data analysis method: Explanatory factors of the actor profitability

In order to obtain insight in the most important constraints in the value chain, factors and characteristics of value chain actors that significantly impact the profitability, we apply a *multiple linear regression analysis* to discern those constraints that significantly impact the profitability. Regression analysis is a statistical forecasting model that describes and evaluates the relationship between a dependent variable and a set of independent variables (Rawlings et al., 1998). A generic multiple linear regression model is presented as follows:

$$Y = \beta_0 + \sum_i \beta_i X_i + \mu \qquad (2.5)$$

with Y dependent variable

X_i independent variable

β_0 constant

β_i coefficient of the independent variable

μ error term

2.4 Empirical Results

In this section, the empirical findings are presented to characterize the rice value chain in Myanmar. In Section 2.4.1, the profitability and the socio-demographic characteristics of the actors are discussed. Section 2.4.2 gives insight in the constraints encountered at each level of the rice value chain. In Section 2.4.3, the socio-demographic and constraint information are related to the profitability of the actors in the supply chain to identify the significant and most important constraints. Note that the presented empirical data applies only for the Emata rice varieties.

2.4.1 Characteristics of the rice value chain in Myanmar

2.4.1.1 Profitability analysis

In this section, we present the empirical results related to the gross marketing margins and the marketing profits along the rice value chain. Note that paddy is marketed in the value chain from farmers through collectors to millers. Since the millers transform the paddy into rice, rice is marketed from millers through wholesaler to retailers or exporters. In this calculation, we account for the conversion of paddy into rice, which is estimated at 60% (Zorya et al., 2016). We calculate the profit and margins of paddy and rice exploited for domestic consumption (Table 2.1) and for export consumption (Table 2.2). This distinction is only apparent in the final stage of the value chain and is based on the distribution channel, i.e. whether the rice is distributed via retailers for domestic consumption or via exporters for export consumption.

The rice value chain is characterized by a wide marketing margin, i.e. a high consumer price for rice and a low farm gate price for paddy. The gross marketing margins and profits are not equally distributed over the different actors. In general, rice millers obtain the highest percentage of the profit share among the value chain actors, i.e. 50.9% for domestic consumer chain and 59.8% for the international consumer chain, which is significantly[2] higher compared to the other actors. This is due to the fact that rice millers purchase the paddy cheap from the farmers at the harvest time when the paddy price is low and they add value by transforming the paddy into rice. Note that this margin of the rice millers may be biased upwards due to the fact that only variable costs are taken into account, whereas capital investment costs are not. These capital investments are the larger for millers compared to the other actors in the value chain.

[2] The applied test is F-test (p-value < 0.001). A post-hoc test (p-value < 0.001) is performed to analyse the pairwise differences between the actors.

The farmers have the highest gross marketing margin, i.e. 44.1% for the domestic consumer chain and 43.3% for the international consumer chain. In contrast, their profit share amounts only 9.0% and 10.6%, respectively. Hence, although the farmers have the highest margin, they still have a lower profit compared to the millers which is the result of their higher production costs.

Table 2.1 Marketing profits and margins of the value chain for domestic consumption

Actor	Costs (MMK/kg)			Revenues (MMK/kg)	Profits (MMK/kg)		Margins (MMK/kg)	
	Unit Total Cost	Unit Added Cost	% Added Cost	Unit Price	Unit Marketing Profit	% Total Marketing Profit	Unit Marketing Margin	% Total Marketing Margin
Farmer	210	210	77.5	236	26	9.0	236	44.1
Primary collector	236	0	0.0	241	5	1.7	5	0.9
Miller	255	39	14.4	402	147	50.9	161	30.1
Wholesaler	413	11	4.1	448	35	12.1	46	8.6
Retailer	459	11	4.1	535	76	26.3	87	16.3
Total		**271**	**100.00**		**289**	**100.0**	**535**	**100.0**

Note: We assumed 1USD = 1350 MMK

Unit total cost of miller (255) = unit price of primary collector (241) - return from byproduct (25) + unit added cost (39)

with Unit Marketing Margin = Selling price per unit – Purchase price per unit

Unit Marketing Profit = Unit marketing margin – Total production/transformation/distribution cost per unit

% Total Marketing Profit = (Marketing profit per unit of each actor/Total marketing profit per unit of all actors) x100

% Total Marketing Margin = (Marketing margin per unit of each actor/Total marketing margin of all actors) x 100

Source: Own survey (2017)

Table 2.2 Marketing profits and margins of the value chain for export consumption

Actor	Costs (MMK/kg)			Revenues (MMK/kg)	Profits (MMK/kg)		Margins (MMK/kg)	
	Unit Total Cost	Unit Added Cost	% Added Cost	Unit Price	Unit Marketing Profit	% Total Marketing Profit	Unit Marketing Margin	% Total Marketing Margin
Farmer	210	210	64.8	236	26	10.6	236	43.3
Primary collector	236	0	0.0	241	5	2.3	5	0.9
Miller	255	39	12.0	402	147	59.8	161	29.5
Wholesaler	413	11	3.4	448	35	14.2	46	8.4
Exporter	512	64	19.8	545	33	13.4	97	17.8
Total		**324**	**100.0**		**246**	**100.0**	**545**	**100.0**

Note: We assumed 1USD = 1350 MMK

Unit total cost of miller (255) = unit price of primary collector (241) - return from byproduct (25) + unit added cost (39)

Source: Own survey (2017)

2.4.1.2 Socio-demographic characteristics

The empirical results related to the socio-demographic characteristics of the respondents in the value chain are presented in Table 2.3.

Table 2.3 Socio-demographic characteristics of the rice value chain actors

Items	Unit	Parameters	Farmer	Primary collector	Miller	Wholesaler	Retailer	Exporter
Gender	Numbers	Male	114(62.0)	19(10.3)	23(12.5)	5(2.7)	19(10.3)	4(2.2)
		Female	16(51.5)	2(6.5)	2(6.5)	2(6.5)	9(29.0)	0(0.0)
Age	Years	Mean	51.1	41.6	50.1	46.7	49.9	43.0
		Min.	27.0	25.0	30.0	41.0	30.0	35.0
		Max.	85.0	60.0	66.0	62.0	72.0	50.0
Family size	Numbers	Mean	4.0	4.0	4.4	4.0	3.6	4.0
		Min.	2.0	1.0	2.0	2.0	2.0	3.0
		Max.	8.0	7.0	8.0	6.0	6.0	6.0
Education	Years	Mean	6.6	9.3	11.0	12.3	9.9	15.0
		Min.	2.0	5.0	5.0	6.0	4.0	15.0
		Max.	15.0	15.0	15.0	15.0	18.0	15.0
Working experience	Years	Mean	27.1	10.8	12.8	13.0	13.6	13.0
		Min.	3.0	1.0	1.0	3.0	1.0	5.0
		Max.	54.0	30.0	33.0	24.0	50.0	26.0

Note: Figures in the parentheses represent percentage.
Source: Own survey (2017)

Gender - According to Table 3, there are a lot of more male actors involved in the rice supply chain than female actors. However, analysis revealed that in the distribution stages, grouping the wholesalers, the retailers and the exporters, significantly[3] more female actors are presented in the supply chain.

Age - The mean age of the actors ranges from 41.6 years to 50.1 years. Statistical analysis revealed that the primary collectors are significantly[4] younger than the other actors but no other differences were noted.

[3] We conducted a Chi-square test (p-value < 0.05).
[4] The applied test is F-test (p-value < 0.05). A post-hoc test (p-value < 0.001) is performed to analyze the pairwise differences between the actors.

Family size - The mean number of family members equals around 4 for all actors in the value chain and there are no significant differences between the different groups.

Education - The education of actors enhances the decision-making and the basic communication abilities with any support service providers such as extension officers and other stakeholders. The education is expressed in Table 2.3 by the number of schooling years and ranges from 6.6 years for farmers (corresponding to the secondary education level) to 15 years for exporters (corresponding to the graduate level). The education level of farmers is significantly[5] lower compared to the other actors. In general, the further upstream in the value chain and the more the involvement in the processing and marketing activities, the higher the education level apart from the retailers.

Work experience - Farmers have the largest number of years of work experience (27.1 years), whereas primary collectors have the smallest number of years (10.8 years). The millers, wholesalers, retailers and exporters have around 13 years of work experience. The work experience of farmers is significantly[5] higher than those of other actors.

2.4.2. Constraints in the rice value chain

This section gives insight in the constraints faced by each actor along the rice value chain in the study area. These constraints hinder the actors to upgrade the value chain and are possibly imposed by external parties. The constraints are categorised into material input constraints, production constraints, financial constraints and distribution and institutional constraints.

2.4.2.1 Farmers

The farmers encounter many different types of constraints (cf. Figure 2.2).

[5] The applied test is F-test (p-value < 0.001). A post-hoc test (p-value < 0.001) is performed to analyze the pairwise differences between the actors.

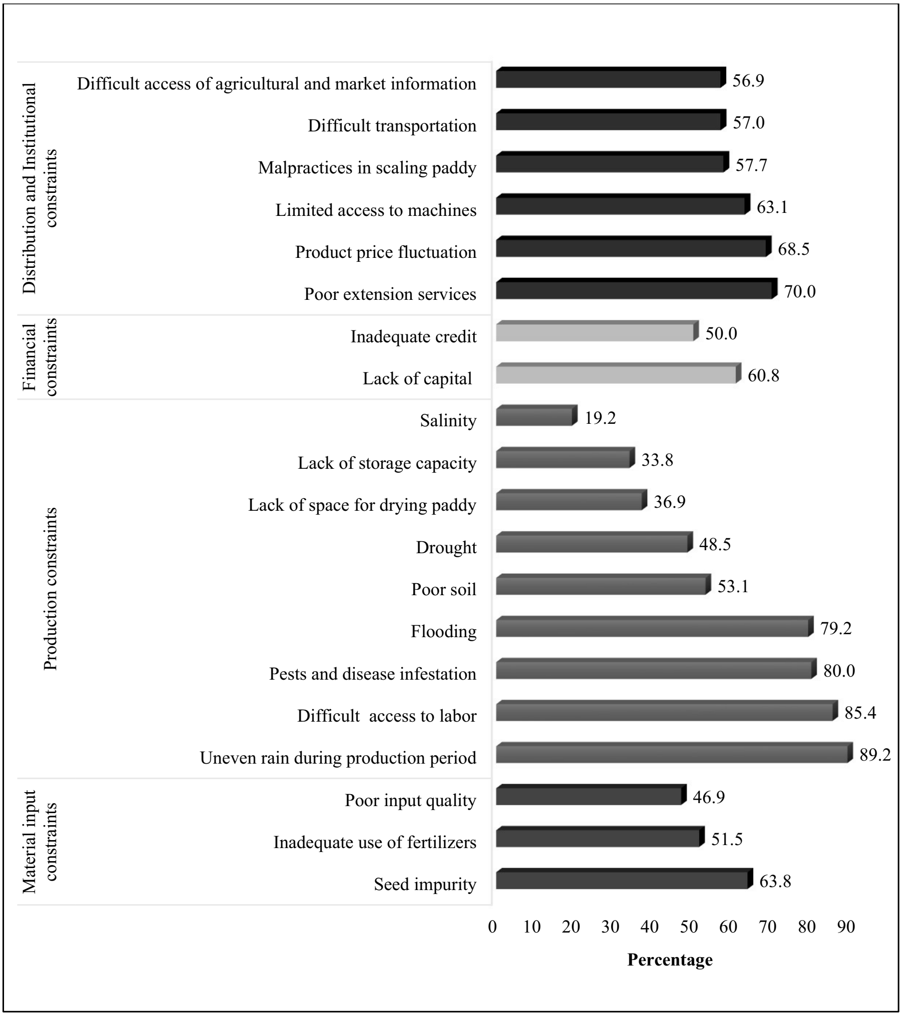

Figure 2.2 Operational constraints for farmers

Source: Own survey (2017)

A large part of the farmers respond that they face different *material input constraints*, i.e. a seed impurity problem (63.8%), the incorrect use of fertilizers (51.5%) or the poor input quality of fertilizers, pesticides, insecticides and chemicals (46.9%). In-depth interviews learned that farmers have an insufficient know-how of the quality of these agrochemicals, which is required to improve the productivity and the product quality. We identified nine different *production constraints*. Among these constraints, five are weather-related constraints such as uneven rain during the production period (89.2%), flooding (79.2%), drought (48.5%), salinity (19.2%) and pest and disease infestation (80%). Further, farmers suffer from labor scarcity (85.4%), which increases the labor cost and the waste of crops. Financial constraints hinder the upgrade of the farming process or product quality. 60.8% and 50% of the farmers face a lack of capital and credit, respectively. Moreover, farmers complain about revenue losses as a result of *distribution constraints*, i.e. fluctuations in the paddy price (68.5%) and inappropriate scaling, weighing and deduction when selling their goods (57.7%). More than 50% of the farmers identify transportation problems resulting from a poor road infrastructure, especially in the rainy season. The *institutional constraints* involve the difficult access for farmers to extension services (70%) and to new agricultural technologies and market information (56.9%). 63.1% of the farmers are not able to invest in agricultural machinery (soil preparation machines, high-technological seeders, inter-cultivators for weeding, etc.) because of the lack of capital and insufficient support from (non-)government organizations.

2.4.2.2 Primary collectors

Figure 2.3 shows that the number of constraints imposed on the primary collectors is limited. Primary collectors would obtain a higher profit, if they have sufficient capital to buy paddy at a low price, store and sell their paddy when the price is higher. However, 28.6% of the primary collectors face a capital shortage and 14.3% have a limited access to credit. The major distribution and institutional constraints are related to the road infrastructure (71.4%) and the poor paddy quality (66.7%).

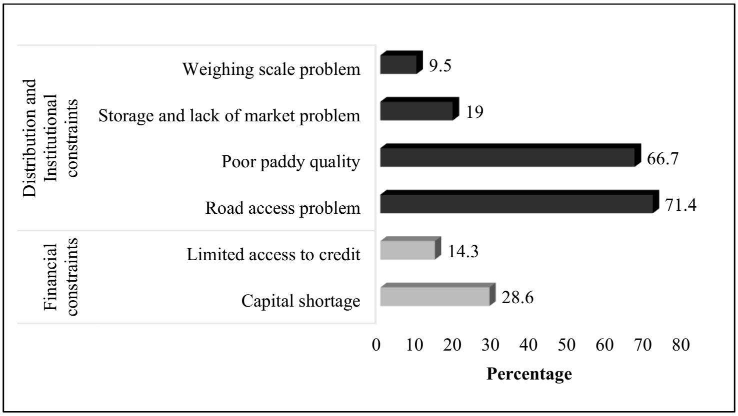

Figure 2.3 Operational constraints for primary collectors
Source: Own survey (2017)

2.4.2.3 Millers

Figure 2.4 reveals that millers face different types of constraints. First, the sample millers face different *production constraints* in order to upgrade their productivity and the quality of the rice produced. All millers encounter problems with the electricity supply. A large part of the rice millers points out that their milling machines are outdated, which leads to frequent machine breakdowns and the need for skillful mechanics to repair these machines. 52% of the rice millers lack an improved polisher and color sorter to increase the rice quality. 48% of the rice millers indicate that they do not have suitable storage facilities. Second, their operations are restricted by *financial constraints* since most of the millers (72%) have a limited access to working capital. Especially the small-scale rice millers cannot collect the required amount of working capital. Third, as *distribution constraints*, the millers face a poor road infrastructure and high transportation cost due to high fuel costs and road toll fees. 68% of the rice millers have the idea to export their rice to other countries directly but they claim that their rice quality is too low for export. This is due to seed impurity, a high proportion of broken rice and improper handling by the farmers.

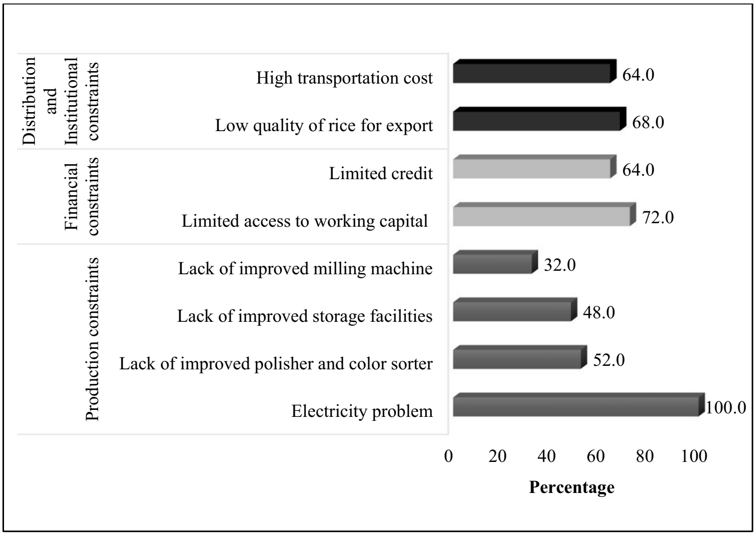

Figure 2.4 Operational constraints of millers

Source: Own survey (2017)

2.4.2.4 Wholesalers

The survey results in Figure 2.5 reveal that the wholesalers face financial, distribution and institutional constraints. Wholesalers need more capital to run or expand their business. However, they face a capital shortage due to the high interest rates, high tax rates and the difficult access to loans, which creates deficiencies in the value chain. Moreover, they face high transportation costs, they lack an adequate market infrastructure and market information and suffer from a high competition.

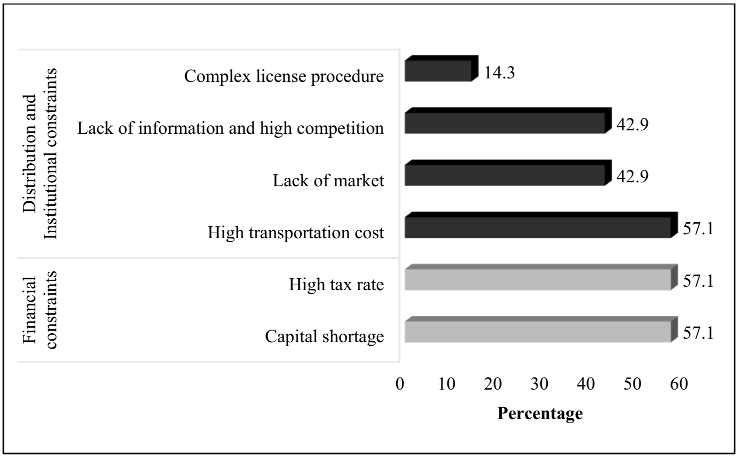

Figure 2.5 Operational constraints of wholesalers

Source: Own survey (2017)

2.4.2.5 Retailers

Retailers encounter financial, distribution and institutional constraints (cf. Figure 2.6). Most of the sampled retailers need more capital to expand their business but they are not able to collect the required credit from third parties. They operate on small, daily markets where they have to pay a fee and high taxes to sell their goods and suffer from a high competition possibly with unlicensed retailers. Moreover, some of the retailers have to order the different rice varieties from other regions depending on the preferences of the consumers and do not have enough storage space. Other constraints are the poor road and a suitable market infrastructure.

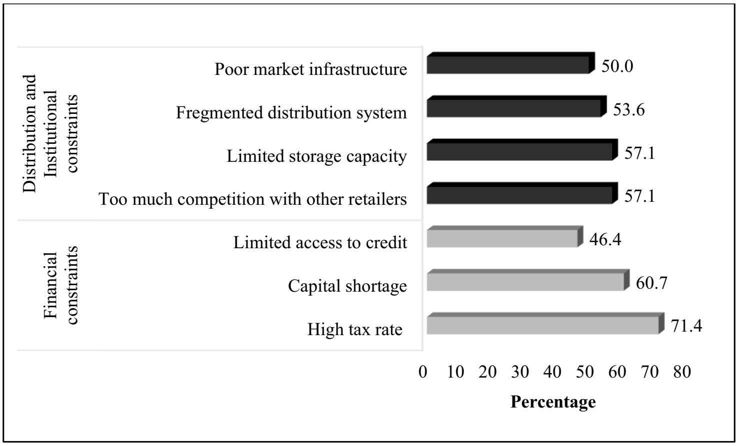

Figure 2.6 Operational constraints of retailers

Source: Own survey (2017)

2.4.2.6 Exporters

Figure 2.7 shows the constraints of rice exporters. Exporters need to process and sort rice to reach the required quality standards. In this process, electricity or power interruption is a major problem, which lengthens the processing time. Exporters encounter financial constraints as they face a high interest rate when they borrow money from the banks. Some of the exporters suggest the government should provide loans with a low interest rate as done in foreign countries. The banks in Myanmar are outdated and have difficulties to execute money transactions to other countries. In these transactions, the fluctuations in the exchange rate is also a problem since they impact the rice commodity price. All exporters face high logistic costs and transportation costs stemming from distribution and institutional constraints. As a result of all these factors, rice exporters in Myanmar have difficulties to compete with the exporters from other rice countries.

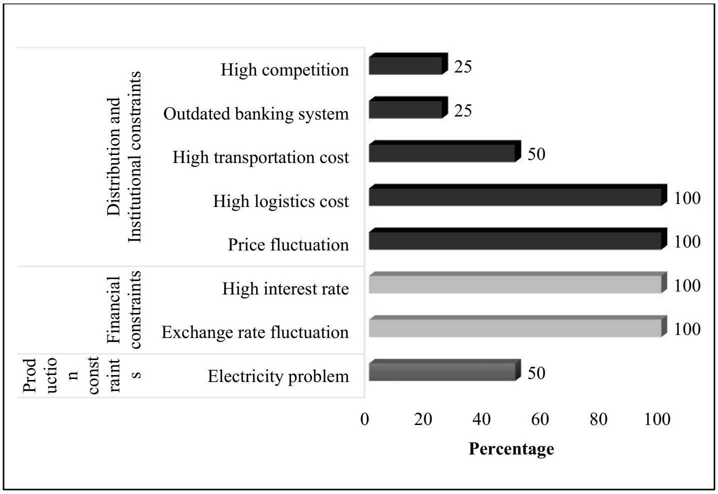

Figure 2.7 Operational constraints of exporters

Source: Own survey (2017)

2.4.3 The impact of operational constraints on the profitability

In this section, we identify the most important and significant operational constraints that impact the profitability of the different actors in the value chain via a multiple regression analysis. The sociodemographic characteristics of the respondents are included in this analysis to increase the accuracy of the findings. The operational constraints and the gender are modelled via binary response variables. The other variables (age, work experience, education, family size) are modelled as integer variables. This analysis could not be conducted for exporters because of the limited number of exporters in the region and for primary collectors since they all have exactly the same profit per unit. In our analysis, only the significant factors are mentioned.

2.4.3.1 Farmers

The results of the regression analysis of the farmer profitability are displayed in Table 2.4. Constraints resulting from natural disasters (i.e. flooding, natural pests and diseases and uneven rain during the production period) are observed to have the largest impact on the profitability of farmers. Farmers who suffer from these natural disasters have a significant lower profit. In addition, a correlation analysis reveals a significant negative impact of the material and/or labor input constraints, i.e. seed impurity ($p < 0.001$), poor input quality (p

= 0.001), inadequate use of fertilizer (p = 0.035) and difficult access to labor availability (p = 0.025) on the profit of farmers. The same is valid for different financial and distribution and institutional constraints, i.e. the lack of capital (p = 0.026), product price fluctuation (p = 0.009), difficult transportation (p < 0.001) and poor extension services (p = 0.011).

The analysis of the socio-demographic characteristics reveals that the age, the education level and the work experience of the farmers show a significant relationship with the profitability and may impact how farmers perceive some constraints. Younger farmers earn more profit than older farmers since they accept easier the new or higher production technologies to increase their productivity. The higher the level of education, the higher the profit as higher educated farmers use their scarce resources more efficiently and effectively (Duy, 2015; Khai and Yabe, 2011 and Linh, 2012) and are better able to adopt the higher technologies in the rice production (Ghimire et al., 2015; Mariano et al., 2012). Further, more experienced farmers earn a higher profit since these farmers have been able to optimize their operations over the years.

Table 2.4 Estimated regression coefficients of factors influencing the profitability of the farmers

Variables	Coefficient	t-value	Significance
(Constant)	77.537	1.286	0.201^{ns}
Gender of the actors (1 = Male, 0 = Female)	37.73	1.614	0.109^{ns}
Age of the actors (Years)	-2.687	-3.063	0.003***
Family size (Number)	-2.573	-0.464	0.644^{ns}
Education of the actors (Schooling years)	7.717	2.381	0.019**
Working experience (Years)	2.829	3.278	0.001***
Flooding (1 = Yes, 0 = No)	-96.293	-5.093	0.000***
Uneven rain during the production period (1 = Yes, 0 = No)	-40.667	-2.119	0.036**
Pests and diseases infestation (1 = Yes, 0 = No)	-48.458	-2.159	0.033**
Difficult transportation (1 = Yes, 0 = No)	-1.721	-0.079	0.937^{ns}
Poor Extension services (1 = Yes, 0 = No)	-9.692	-0.432	0.667^{ns}
R	0.719		
R Square	0.518		
Adjusted R Square	0.477		
F-value	12.77		0.000***

Note: *** = Significant at 1% level, ** = Significant at 5% level and ns = Non-significant

Multicollinearity problem is not encountered in the model as all predictors for the value chain actors have VIF of less than 5.

The overall model is statistically significant at the 1% level as indicated by the F-value 12.77.

Source: Own survey (2017)

2.4.3.2 Millers

Table 2.5 displays the estimated coefficients of the factors that may impact the profit of rice millers, resulting from the multiple regression analysis. Note that 84.2% of the variance in the profit of millers is explained by the independent variables included in the regression model, which indicates that the model is able to obtain an accurate profit prediction. The operations of rice millers are negatively impacted especially by financial constraints and distribution and institutional constraints. The high transportation costs have the largest impact on the profit of rice millers ($p = 0.002$). Millers that obtain rice of lower quality are not able to distribute rice to exporters, which leads to a lower profit ($p = 0.061$). The limited access to working capital and credit impacts the profit ($p = 0.047$) since millers with a lack of capital are not able to purchase new technology to improve their productivity. There is, however, a significant and positive relationship with some sociodemographic factors such as the number of schooling years ($p = 0.001$) and the work experience of rice millers ($p = 0.055$). Higher educated millers adopt easier modern milling methods leading to a higher productivity and profit. In addition, more experienced millers are more skilled to lead their operations and are able to attain a larger profit margin.

Table 2.5 Estimated regression coefficients of factors influencing the profitability of the millers

Variables	Coefficient	t-value	Significance
(Constant)	118.462	3.912	0.001***
Gender of the actors (1 = Male, 0 = Female)	13.996	0.979	0.343 ns
Age of the actors (Years)	-0.044	-0.114	0.911 ns
Family size (Number)	2.393	0.79	0.442 ns
Education of the actors (Schooling years)	4.214	4.376	0.001***
Working experience (Years)	1.129	2.081	0.055*
Capital shortage (1 = Yes, 0 = No)	-16.796	-2.159	0.047**
Low quality of rice for export (1 = Yes, 0 = No)	-16.119	-2.027	0.061*
Lack of improved rice huller and polisher (1 = Yes, 0 = No)	-4.326	-0.631	0.538ns
High transportation cost (1 = Yes, 0 = No)	-25.622	-3.652	0.002***
R	0.918		
R Square	0.842		
Adjusted R Square	0.747		
F-value	8.886		0.000***

Note: *** = Significant at 1% level, ** = Significant at 5 % level, * = Significant at 10 % level and ns = Non-significant

Multicollinearity problem is not encountered in the model as all predictors for the value chain actors have VIF of less than 5.

The overall model is statistically significant at 1% level as indicated by the F-value 8.886.

Source: Own survey (2017)

2.4.3.3 Wholesalers

Due to the small sample size, regression analysis was not applicable to identify the constraints with a significant impact on the wholesalers' profit. Instead, a correlation analysis is applied. The wholesalers suffer from a limited access to working capital ($p = 0.040$) to expand their business and from the high transportation costs ($p = 0.014$).

2.4.3.4 Retailers

The results of the regression analysis to identify the most significant constraints of retailers are displayed in Table 2.6. Note that the independent variables included explain 83.4% of the variance and are thus able to predict the retailer profit in an accurate manner. The profit of retailers is impacted by financial, distribution and institutional constraints. Especially, the retailers that experience high taxes and other fees have a significantly lower profit ($p = 0.030$). Moreover, retailers obtain a lower profit when they face a severe competition (p =

0.010). The further analysis of the socio-demographic factors shows that higher educated and more experienced retailers are more competitive. The higher the level of education, the higher the level of advanced knowledge to market rice leading to a higher profit (p = 0.037). Retailers with more experience are more skilled and obtain a higher profit (p = 0.006).

Table 2. 6 Estimated regression coefficients of factors influencing the profitability of the retailers

Variables	Coefficient	t-value	Significance
(Constant)	46.24	1.93	0.070^{*}
Age of the actors (Years)	0.087	0.254	0.802^{ns}
Gender of the actors (1 = Male, 0 = Female)	-6.074	-1.044	0.310^{ns}
Family size (Number)	-0.231	-0.08	0.937^{ns}
Education of the actors (Schooling years)	1.784	2.258	0.037^{**}
Working experience (Years)	0.923	3.082	0.006^{***}
Faced with poor infrastructure (1 = Yes, 0 = No)	2.832	0.479	0.637^{ns}
Capital shortage (1 = Yes, 0 = No)	-5.287	-0.911	0.374^{ns}
High taxation and other fees (1 = Yes, 0 = No)	-17.211	-2.357	0.030^{**}
Too much competition with other retailers (1 = Yes, 0 = No)	-19.925	-2.859	0.010^{***}
R	0.913		
R Square	0.834		
Adjusted R Square	0.751		
F-value	10.071		0.000^{***}

Note: *** = Significant at 1 % level, ** = Significant at 5% level, * = Significant at 10% level and ns = Non-significant
Multicollinearity problem is not encountered in the model as all predictors for the value chain actors have VIF of less than 5.
The overall model is statistically significant at the 1% level as indicated by the F-value 10.071.
Source: Own survey (2017)

2.5 Discussion

The rice value chain in the Ayeyarwaddy Region is characterized by a large number of steps and operational constraints that hinder the profitability and the further development of the rice value chain. The structure of the value chain in the region is similar to the rice value chain in Cambodia (Kula et al., 2015). In Thailand, however, Maneechansook (2011) revealed the presence of *cooperatives* of farmers and *brokers*, which operate on the national and international market as intermediary parties. These actors improve the market access and market knowledge and have increased the competitiveness of the rice industry of

Thailand as a result from the increased bargaining power at different stages of the value chain. In the studied region, the gains are not distributed equally over the actors. Millers obtain the largest profits while farmers obtain a profit, which is lower than most actors. The study of Maneechansook (2011) came to similar conclusions for the rice industry in Thailand. However, the profits are more balanced between the actors and are relatively higher for farmers and intermediary parties.

The profit and the potential upgrade of the value chain is heavily determined by the operational constraints imposed in the different stages of the rice value chain. In the following, we will discuss the challenges associated with the constraints identified as most important for each stage of the value chain and the constraints that are returning over different stages. Figure 2.8 gives an overview of the challenges for the rice value chain in Myanmar. In addition, we pinpoint the parties from the government, private sector, development partners and civil society that are best placed to cope with these constraints.

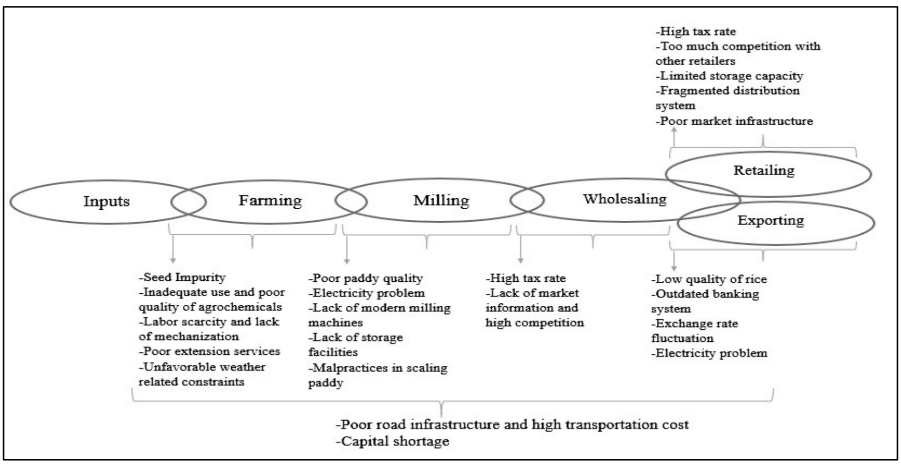

Figure 2.8 Overview of the operational constraints in the rice value chain in the study area

Source: Own survey (2017)

2.5.1 The farmers and their inputs

The analysis of the operational constraints revealed that farmers, vital for the produced rice quantity and quality, are a very vulnerable party in the chain as they are exposed to many constraints. These constraints are in line with the literature (De Janvry and Sadoulet, 2005; Reardon and Barret, 2000), which states that farmers in developing countries have a competitive disadvantage because they have limited capital, use traditional techniques, depend on family labor and lack contact with (international) market players.

Farmers in the Ayeyarwaddy Region are foremost impeded by *natural disasters*. Unfavorable weather conditions (e.g. flooding, uneven rain) cannot be avoided. However, in dialogue with the stakeholders, risk mitigation strategies should be developed, and different actions can be undertaken in order to increase the yield of farmers. Public awareness of the impact of climate conditions on the agricultural production systems deserves priority consideration and mitigating technologies must be developed, which will require increased public and private investment. Accurate weather forecasts are crucial for farmers to organize their activities in a proactive manner. The Department of Agriculture and the Department of Meteorology should educate the farmers via extension services how to effectively use weather information for their agricultural activities and how to deal with adverse climate conditions. Best practices such as switching cultivating time, using flood resistant rice varieties, etc. should be widespread among the farmers in the region. In addition, the government and the private sectors should offer new financial climate crop insurance mechanisms to protect the farmers.

The second major type of constraints is related to the *input materials*. Seeds, agrochemicals, etc. significantly impact the productivity and the rice quality, which is identified in this and later stages of the chain as a restrictive factor to upgrade the value chain and increase the profit. The availability of good-quality and pure seeds is essential to increase the yield and the quality of the rice production and to become a significant exporter in the global rice market. The seeds used by most of the farmers are impure because they produce the seeds on their own farms using traditional methods. This finding is in line with the study of Wong and Wai (2013). As a response, the functioning of the (state) seed production companies should be revised such that all farmers have access to high-quality seeds at the least possible cost. Other improvements can be realized via better regulating the price and quality of agrochemicals such as fertilizers, pesticides and herbicides. Nowadays, very expensive, unregistered and/or banned agrochemicals enter the input market in Myanmar, which is confirmed by Wong and Wai (2013) and similar to the findings of Rong (2013) in Cambodia. Therefore, the government should warrant that the Fertilizer Law and the Pesticide Law are respected in a stricter sense. The entry of agrochemical products into the market should be regulated and registered to ensure the quality standards. In addition, farmers should be educated via extension services to have a better knowledge about the quality of agrochemicals and its proper utilization.

The crop cultivation is further hindered by *labor scarcity* and traditional farming activities, which may be solved via the promotion and adoption of farm mechanization for preparation, cultivation and post-harvest activities. Therefore, the government should develop a farm mechanization and cultivation program in cooperation with private institutions and make several interventions such as the provision of the appropriate (public) infrastructure ready for mechanization, the knowledge transfer to learn farmers how to adapt their farm and farming techniques and the acquisition of farm machinery by farmers via low interest loans.

Most of these constraints can only be removed if more and better a*gricultural extension services* are offered to farmers, which is confirmed by the studies of Rong (2013) and Wong and Wai (2013). The main responsible institution is MOALI, which should cooperate with non-government organizations (NGOs) and private agrochemical companies for delivering extension education programs to farmers in a more efficient manner. The extension system needs to be reformed, i.e. the mobility of extension officers should be increased, the links between farmers, researchers and extension staff should be improved and farmers should be encouraged to learn the latest technologies and new skills required for the new global agricultural era.

2.5.2 The millers and their inputs

The millers take a prominent place in the rice value chain as they obtain the largest profit share. The operational constraints imposed on the operations of millers have in general a smaller impact on their profit compared to the farmers. However, in order to increase the competitiveness of the rice value chain different constraints should be facilitated. In general, the *infrastructure* of the rice millers is insufficient and outdated. The frequent power outages during the milling process is a main constraint for the millers and hinders an increase of the productivity. The storage facilities are insufficient to properly store large amounts of rice.

Many millers use outdated machines to process the rice leading to an inferior rice quality, which is also the case in Cambodia (Rong, 2013). There is lack of a standard weighing system that is fair for all stakeholders and would smoothen the rice value chain. Major investments are required to achieve a higher productivity and rice quality, suitable for export. The government needs to renew the power infrastructure. Millers, however, are not able to invest in storage facilities and high-quality modern milling machines due to financial constraints, i.e. capital shortage and high interest rates for loans. Moreover, the paddy delivered by the farmers is often of lower quality because of inappropriate cultivation and post-harvest drying practices of farmers. As a result, there is a high percentage of rice broken after the milling process strengthened by the outdated milling machines (Rong, 2013; Wong and Wai, 2013).

2.5.3 The wholesalers and retailers

The wholesalers and retailers carry out an intermediary role in the supply chain, but are confined. The tax payments related to the business license, marketing license, municipal tax etc. are high for the actors given their profit. As a result, many unlicensed retailers operate on the market creating a more severe competition. Further, the market information is very fragmented with many different companies because of the lack of horizontal and vertical cooperation in the value chain. The market price information from the nearest market, supply/demand situation from focal point, and policy environment are important factors in the wholesaler's decision-making process. Therefore, intermediary parties should centralize the correct and real-time market information in order to improve the supply chain efficiently.

2.5.4 The exporters and their inputs

Exporters operate on the international market where a substantial increase in revenues and value can be realized similar to neighboring ASEAN countries. However, several operational constraints hinder this upgrade and the increase of the competitiveness of Myanmar.

The *yield* and *low quality of rice produced* is the main constraint on the growth as both are not up to standard. Myanmar has an increasing demand on the international market for a rich diversity of traditional rice varieties, which have a high branding and marketing potential. As discussed, all stakeholders in the chain should cooperate and have their responsibility to achieve a higher productivity and quality standard of rice. Moreover, exporters face different financial constraints in their international transactions, i.e. difficult international money transfers, a higher interest rate in Myanmar compared to international banks, exchange rate fluctuations cause price fluctuations in the entire supply chain and an unstable market structure. Therefore, the government should reform their activities in cooperation with the bank sector and develop an effective monetary policy.

2.5.5 The entire supply chain

A major issue to upgrade the value chain is the lack of financial means, i.e. credit or working capital, experienced by all actors in the supply chain. Farmers need affordable paddy loans to prepare the land and buy input materials, which is mainly the responsibility of Myanmar Agricultural Development Bank (MADB). Farmers, millers and distributors (wholesalers, retailers and exporters) need all low interest investment credits to modernize and expand their operations and infrastructure such that the production and rice quality can be increased. Credits should be supported by banks in cooperation with government organizations and interested private partners. Moreover, the different actors in the supply chain, especially those having a distribution role in the chain, suffer from difficult transportation, high transportation and logistics costs as a result of poor road access and high fuel costs. For that purpose, the government should revise and update the road infrastructure in cooperation with the private sector in order to improve its reliability and minimize the transportation costs.

2.6 Conclusion and Recommendations

The value chain of the rice supply chain in the Ayeyarwaddy Region of Myanmar is structured in an inefficient manner, characterized by a large number of actors who face a large number of constraints. The gross marketing margin across the global value chain is very wide and is not equally distributed over the different actors. Not all actors receive a reasonable profit margin. The rice miller is by far the most profitable actor whereas the farmers are the most vulnerable actors in the value chain given their moderate profit margin and the large number of constraints imposed. Education and experience of the actors are positively and significantly related to their profitability. The actors suffer especially from material input constraints, production constraints, financial constraints and distributional and institutional constraints. All these constraints have a significant and negative impact on the profitability of the actors and hinder the further development of the value chain. The described constraints highlight the array of key issues that must be resolved to upgrade the rice value chain. However, priorities should be set to accomplish a feasible and gradual progress of the value chain.

First of all, the stakeholders should be encouraged to undertake different actions to improve the quality of rice. Therefore, the government and private partners are responsible to secure the availability of high-quality production inputs (seeds, fertilizers, chemicals). The government should strictly control these inputs. In addition, farmers should be encouraged to have a better knowledge of cultivation and post-harvesting techniques, climate risk mitigation strategies and new technologies via more efficient extension services. The educational status and experiences of the actors enhances the decision making and the basic communication abilities with any support service providers such as extension officers and other stakeholders in the business. The government needs to invest in this extension program by training the skills of the extension staff and providing sufficient logistic support. Simultaneously, farmers and other roles in the value chain should organize themselves in cooperatives in order to increase the bargaining power on the national and international market, similar to other ASEAN countries. In this way, price fluctuations will be less volatile, more accurate market information can be gathered and a better market orientation is obtained, which is essential for the effective working of the value chain.

Second, investments in the different stages are needed as the rice value chain in this study area is still very traditional. Therefore, the actors need sufficient working capital, which may be increased via previous actions, or should have the possibility to obtain low interest loans via banks, private parties or the government. In this way, farmers and millers may implement the mechanization of their operations to increase the rice production significantly and further improve the rice quality. These loans will also allow distributors to expand their business.

Third, the government in collaboration with the private sector needs to invest in the existing road, power and market infrastructure. The development of the road network will increase the access to the markets and avoid inefficiencies in transport and logistics. This will decrease the (transportation) costs and increase the market competitiveness.

Future research should give more insights in order to further develop the rice value chain of Myanmar. A benchmark of the efficient practices of actors can enhance the productivity, profit and the amount of rice marketed of the entire value chain. Therefore, the efficiency of the actors should be evaluated and compared. Best practices should be widespread via extension services. Moreover, the productivity and product quality of the agricultural value chain is heavily affected by uncertainties, which even may cancel out the intended effect of government or private policies. Therefore, the main sources of uncertainty encountered by the different parties in the rice supply chain should be identified.

2.A Appendix

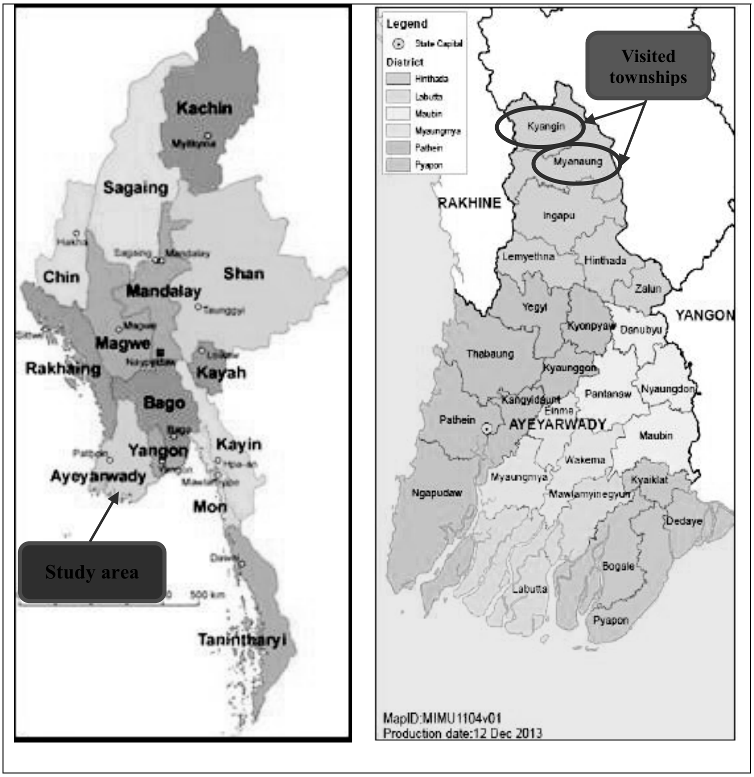

Figure 2.A.1 Map of Myanmar and Ayeyarwaddy Region which shows the studied townships

Source: Department of Agriculture (DOA), 2017

Table 2.A.1 Sampled respondents along the rice value chain in the study area

Actors	Townships	Total Population	Sampled respondents
Farmers	Myanaung (Laharpauk village)	399	30
	Myanaung (Htanthonepin village)	327	30
	Kyangin (Kyantaw village)	663	35
	Kyangin (Sonehele village)	630	35
Collectors	Myanaung	105	15
	Kyangin	60	6
Millers	Myanaung	132	18
	Kyangin	80	7
Wholesalers	Myanaung	34	4
	Kyangin	20	3
Retailers	Myanaung	103	20
	Kyangin	61	8
Rice Exporters	Yangon	36	4
	Total respondents		**215**

Source: DOA (2017) and MRF (2017)

3

The Impact of Uncertainty on the Performance of the Rice Supply Chain in the Ayeyarwaddy Region, Myanmar

In this paper, we study the relationship between uncertainty and performance in the rice supply chain in the Ayeyarwaddy Region, Myanmar. The sources of uncertainty in agri-food supply chains are different from the general supply chain due to the perishability of products, variable harvest and production yields, and the vast impact of climate conditions on upstream and downstream activities. Efficiency is one of the important performance indicators in both supply chain and agribusiness. In this regard, the objectives of the study are to identify the different sources of uncertainty perceived by the different actors in the rice supply chain in the Ayeyarwaddy Region, to measure the rice supply chain efficiency and to study the impact of uncertainty on the supply chain efficiency. The data of 215 respondents is collected from the Ayeyarwaddy Region by using a purposive and stratified random sampling method and we analyse this data via descriptive statistics, an exploratory factor analysis, Data Envelopment Analysis (DEA) and Tobit regression analysis. The results reveal that among seven major sources of uncertainty, the climate uncertainty is the most important factor followed by uncertainty in planning and control. The analysis of the technical, pure and scale efficiency show a very low performance of the rice supply chain in the Ayeyarwaddy Region resulting from the fact that most of the rice businesses are too small and need to expand their operating size. We found that this global rice supply chain performance is significantly impacted by the planning and control uncertainty and the climate uncertainty. Therefore, capturing and sharing information in the supply chain is crucial to operational control and planning because a higher quality of information input will increase the quality of managerial decision making. Moreover, public awareness of the impact of climate conditions on the agricultural production systems deserves priority consideration. Mitigating technologies must be developed to reduce the impact of the climate adverse conditions, which will require increased public and private investment.

3.1 Introduction

Agriculture plays a major role in Myanmar's society by ensuring food security at community and national levels as well as in the provision of employment and income for a growing population. Agriculture is essential to the domestic economy of Myanmar. In 2014-2015, 22.1 % of GDP resulted from agricultural activities (MOAI, 2015a). More than half of the population is directly employed in this sector. The agricultural sector is considered as one of the major driving forces for economic growth and the heart for improving of social wellbeing (World Bank, 2014). Moreover, rice contributes export earnings to the economy of the country and provides food security and poverty reduction in Myanmar. In 2016, the paddy production in Myanmar was ranked 7th of the paddy producing countries in the world (World Rice Production, 2017). Rice is the country's most important agricultural product by far, accounting for about half of all cultivated land. In 2015-16, the sown areas and production of paddy in Myanmar is 7.21 million hectares and 27.16 million metric tons, respectively (MOALI, 2016). Most of the household income is earned from rice farming and related activities, especially in major rice growing area of Ayeyarwaddy, Bago, and Sagaing Regions in Myanmar. The Ayeyarwaddy Region is the main rice growing area in Myanmar and occupies 25% of Myanmar's rice acreage and the use of farm mechanization in the region is very low with 251 tractors and 83 combined harvesters (AMD, 2015).

In most developing countries, governments, development agencies and private sectors recognize the role of poverty reduction and food security and, as a result, are increasingly investing in agricultural value chains, providing inputs, financing and other services that support their development. Over the past five decades, food availability has been greatly improved through productivity gains in the agricultural sector (Baldos and Hertel, 2014). However, the agricultural sector is currently under increasing pressure, i.e. (i) to be sustainably run, which implies that the sector should be able to meet the needs of the present without compromising the ability of future generations to achieve their own ends, and (ii) to provide food, energy and industrial resources to satisfy the demand of a rising world population (Yakovleva et al., 2012). At the same time, there is an increasing awareness that uncertainty impacts the sustainability of a value chain and the performance of the entire supply chain and of each of the involved actors. In an agricultural supply chain, uncertainty can emerge either from an internal or an external source in the supply chain. Some sources of uncertainty are different compared to general supply chains, i.e., the perishability of products, variable harvest and production yields and the huge impact of climate and environmental conditions on upstream and downstream activities (van der Vorst and Beulens, 2002; Wijnands and Ondersteijn, 2006). Moreover, the operational complexity resulting from uncertainty related to the high variability in consumer demand, production and supply lead times, varying quantity and quality standards of products, trade and buffer stock traceability, etc. expose the chain to severe disruptions (van der Vorst et al., 2000; Dong, 2006; Taylor and Fearne, 2006).

In Myanmar, in particular, far lower profits are gained from producing rice compared to other countries in Asia (Zorya, 2016). The agricultural sector has suffered persistently from insufficient investment in technology transfer, research and extension services, infrastructure development, value chain upgrading and marketing (IFAD, 2017). The Ministry of Agriculture and Irrigation has mapped the principal challenges and strategic objectives in order to further develop and upgrade the rice value chain via investments (MOAI, 2015b). According to these challenges and objectives, the rice value chain in Myanmar is not well integrated and efficiency should be improved to increase the market value of rice production and the rice food quality via well-focused investments. However, the Ministry of Agriculture and Irrigation of Myanmar has expressed its concerns regarding the impact of uncertainty in particular related to the climate, the price volatility and arising from the unsatisfactory integration of the value chain over the different actors in the chain from rice production to trading and marketing (MOAI, 2015b).

In this paper, we study in an explorative manner the sources of uncertainty that impact the rice supply chain performance in the Ayeyarwaddy Region in Myanmar. In this way, we learn to understand the challenges the supply chain in the region is dealing with and we can establish priorities. This helps to identify solutions to improve the supply chain operations. To that purpose, we exploit a three-step solution methodology. In a first step, we measure the environmental uncertainty perceived by the various actors in the supply chain. We carried out a questionnaire survey and a statistical analysis to identify the main sources of uncertainty encountered by the different parties in the rice supply chain, i.e., farmers, primary collectors, millers, wholesalers, retailers and exporters. In a second step, we measure the efficiency performance of the different sample respondents per actor category in the rice supply chain via Data Envelopment Analysis (DEA). In a third step, regression analysis is applied to identify the significant sources of uncertainty that impact the performance of the supply chain. Iets zeggen over resultaten?

The remainder of the paper is organized as follows. Section 3.2 reviews the relevant literature on the uncertainty along the agricultural supply chain, the relevant indicators to measure the supply chain performance and in particular the DEA approach, which is used in this study to benchmark the supply chain efficiency. In Section 3.3, the methodology is described to identify the main sources of uncertainty that impact the supply chain efficiency. The findings of our study are revealed in Section 3.4. First, we present the sources of uncertainty as perceived by the actors in the rice supply chain. Second, we measure the performance of the rice supply chain via DEA. Third, we study the impact of the uncertainty on the supply chain efficiency. A conclusion and some policy recommendation are summarized in Section 3.5.

3.2 Literature Review

3.2.1 The Rice Value Chain in Myanmar

Agricultural value chains involve a sequence of value-adding activities to bring products from the farm to the final consumer. The activities in a value chain link together the inputs from providers, farmers, processors, retailers and consumers and create relationships that enable the effective functioning of the value chain (Baldos and Hertel, 2014). The agricultural supply chain includes all functions such as the input provision, production, post-harvest, storage, processing, marketing and distribution, food service and consumption for a given agricultural product (Jaffee et al., 2010).

The rice value chain of Myanmar has been studied by Wong and Wai (2013). The structure of the rice value chain in the study area is shown in Figure 1. The farmers buy inputs such as agrochemicals, machinery, seeds, credit, etc. to farmers for the paddy production from the input suppliers and grow and sell paddy. Primary collectors buy the paddy from the farmers with the financial support of millers. The millers buy and mill the paddy to rice. They carry out different activities that add value such as transportation, processing, grading and packing. The millers store and distribute rice mainly to wholesalers. Wholesalers deliver rice on their turn to retailers in order to supply the domestic consumers or to exporters who supply consumers in foreign countries.

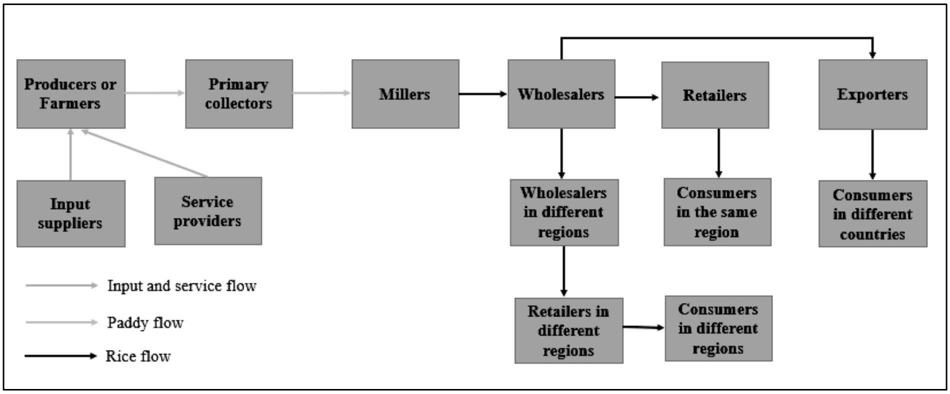

Figure 3.1 Structure of the rice value chain in the study area

Source: Own survey (2017)

A study issued by the Ministry of Agriculture and Irrigation (MAOI, 2015b) posed that the rice value chain in Myanmar is not well integrated and its efficiency should be improved. The supply chain is fragmented as there are too many different parties in the different stages and too many stages ranging from between the farmer and the end consumer. Compared to the neighboring countries Thailand and Vietnam, the rice value chain in Myanmar is characterized by a less efficient input supply system, a lower farm productivity and profitability, higher milling and export costs and a lower quality of exported rice (Zorya et al., 2016). As a result, the rice sector is less competitive on the international market.

3.2.2 Uncertainty in supply chains

Many researchers have investigated uncertainty as an important factor affecting supply chain implementation and performance (Bhatnagar and Sohal, 2005). According to Miller (1993), uncertainty refers to the unpredictability of environmental or organizational variables that have an impact on corporate performance. Carter et al. (2015) stated that supply chain uncertainty can occur at multiple levels, including the level of individual decision makers, functional departments, organizations and, ultimately, supply chains. Uncertainty propagates throughout the network and leads to inefficient processing and non-value adding activities (Patil, 2012). Throughout the supply chain, agents are faced with different sources of uncertainty which may be exogenous, endogenous or both (Chaudhuri et al., 2014).

According to Miller (1992), Davis (1993), Prater (2005) and Lee (2002), supply chain uncertainty has been widely recognized as an issue in modern supply chain and logistics.

Uncertainties in a supply chain may cause delays, lead to a bottleneck and may hinder the performance of the entire supply chain. Literature stated that it is important to consider uncertainties to achieve operational excellence and smooth operations in every link of the supply chain since uncertainty cannot be avoided (Wang et al., 2014). Uncertainty factors in the supply chain involve *supply uncertainty* (Davis, 1993, Towill et al., 2002; van der Vorst and Beulens, 2002; Sawhney, 2006; Thongrattana and Jie, 2009; Patil, 2012 and Chaudhuri et al., 2014), *demand uncertainty* (Lee et al., 1997; Lee, 2002; van der Vorst and Beulens, 2002; Sun et al., 2009; Thongrattana and Jie, 2009 and Patil, 2012), *process uncertainty* (Ettile and Reza, 1992; Miller, 1992; Davis, 1993; Koh et al., 2002; Towill et al., 2002; van der Vorst and Beulens, 2002; Sawhney, 2006; Thongrattana and Jie, 2009 and Patil, 2012), *control and planning uncertainty* (Wilding, 1998; Geary et al., 2002; Towill et al., 2002; van der Vorst and Beulens, 2002; Childerhouse and Towill, 2004; Prater, 2005 and Thongrattana and Jie, 2009), *competitor uncertainty* (Ettile and Reza, 1992; Miller, 1992; Davis, 1993; van der Vorst and Beulens, 2002; Bhatnagar and Sohal, 2005; Paulraj and Chen, 2007 and Thongrattana and Jie, 2009), *government uncertainty* (Miller, 1992; van der Vorst and Beulens, 2002; Christopher and Peck, 2004 and Thongrattana and Jie, 2009) and *climate uncertainty* (Miller, 1992; Christopher and Peck, 2004; Kleindorfer and Saad, 2005 and Thongrattana and Jie, 2009). Note that these factors are perceived differently across industries and countries.

3.2.3 Performance measurement in supply chains

Neely et al. (1991) defined performance measurement as the process of measuring the efficiency and effectiveness of an action. According to Aramyan et al. (2006); Aramyan et al. (2009); Chowarut (2009) and Shen et al. (2013), performance measurement has gained attention in the agri-food chains and various performance measurements have been used. In marketing and supply chain management literature, supply chain performance is measured via different methods such as Activity-Based Costing, Balanced Scorecard, Economic Value Added, Multi-criteria Analysis, Life-cycle Analysis, Data Envelopment Analysis and Supply Chain Operations Reference model. Among these methods, Data Envelopment Analysis (DEA) is a powerful analysis model to calculate the efficiency score of the supply chain performance in various sectors. DEA evaluates the involved business units with multiple inputs and outputs and takes the qualitative and quantitative measures into account (Shafiee et al., 2014). DEA model was used to measure the supply chain performance in various studies (Liu et al., 2000; Easton et al., 2002; Talluri and Barker, 2002; Biehl et al., 2006; Min and Joo, 2006; Reiner and Hofmann, 2006; Li and Dai, 2009; Saranga and Moser, 2010; Jalalvand et al., 2011; Liang et al., 2011; Sanei and Mamizadeh-Chatghayeh, 2013; Shafiee et al., 2014; Rezaei and Adressi, 2015 and Shewell and Migiro, 2016) in different application areas, e.g. the shipping industry (Pattanamekar et al., 2011), the pharmaceutical industry (Mishra, 2012), the dairy industry (Mor and Sharma, 2012) and the vegetable food industry (Lu, 2006).

Uncertainty has a major impact on the performance of the supply chain and managerial decisions. van der Vorst and Beulens (2002) pointed out that the literature recognizes that uncertainties in supply, process and demand have a major impact on the manufacturing function. Thongrattana and Robertson (2008) investigated that periodic rice production losses due to a drought year may create significant problems such as inventory level fluctuations, stock-outs and unfulfilled customer demand. The findings of Thongrattana and Jie (2009) showed that demand and climate uncertainty lead to a significant decrease in efficiency of the rice milling process in Thailand. The empirical model of Matanda and Schroder (2002) measured uncertainty by means of competitive intensity and market turbulence and pointed out that these uncertainty measurements had a direct negative impact on the performance. The relationship between uncertainty based on subjective perceptions by the involved decision makers and performance has been widely studied in research areas such as management accounting but also in supply chain management (e.g. Buchko, 1994; Flynn et al., 2016; Jusoh, 2010; Thongrattana PT and Robertson, 2008; Wong et al., 2011).

3.3 Research Methodology

In this study, we aim to identify the major sources of uncertainty that impact the performance of the rice supply chain. In this way, directions can be determined to improve the efficiency, i.e. to utilize the scarce resources more efficiently and to adopt the right scale of operations. Efficient farm practices can enhance productivity, the farmers' profit and the amount of rice marketed, which improve the competitiveness of Myanmar's rice sector (MOAI, 2015b; Saysay, 2016). To that purpose, we have employed a three-step methodology for which the specific techniques used in each step are explained in the subsections below, i.e.

Step 1: Identify the sources of uncertainty perceived by the different actors in the rice supply chain

Different organizational theorists (e.g. Duncan (1972); Hofer and Schendel (1978); Ansoff (1979); Miles (1982); Rhyne (1985)) established the link between the perceived environmental uncertainty and performance. Organizations must adapt to their environment if they are to remain viable. One of the central issues in this process from the perspective of the decision-making units is coping with uncertainty resulting from environmental factors. The environmental uncertainty and its associated factors are defined in terms of perception of the respondents given the role of individuals in the decision-making process. The research of Duncan (1972) showed that although there are difficulties in getting respondents to verbalize their views of uncertainty, there is a remarkable degree of similarity in the way in which the concept was ultimately defined. Miles et al. (1974) also theorize that managers respond primarily to what they perceive. Strategic action is dependent upon perceptions and interpretations of the environment. In this research, we identify the components of this environmental uncertainty for the entire rice supply chain in Myanmar and identify different degrees of uncertainty as perceived by individuals in decision-making, i.e. the different actors in the rice supply chain, taking their actor role into account. This study is based on the development of a questionnaire and conducting this survey via in-depth and key informant interviews (cf. Section 3.3.1). The results for this questionnaire are checked for its validity and reliability and a factor analysis is applied for measuring the sources of uncertainty and a principal component analysis is applied to reduce the number of variables (cf. Section 3.3.2).

Step 2: Measure the rice supply chain efficiency to assess the supply chain performance

Based on his perception, the decision maker will take the relevant strategic and operational decisions, i.e. he will determine the mix of inputs to maximize his output level and his scale of operations. Hence, we can conclude that from the perception of uncertainty, the decision maker within a company can change the level of efficiency. In order to relate the perceived uncertainty with the efficiency level of the actors, we measure the efficiency by making use of Data Envelopment Analysis (DEA) (Charnes et al., 1978) (cf. Section 3.3.3). Using this technique, we can measure the overall technical efficiency, pure technical efficiency and scale efficiency for all actors in the supply chain, i.e. farmers (production stage), millers (processing stage) and distributors such as wholesalers, retailers and exporters (distribution stage). The marketed amount of paddy is considered as the output variable. The production, financial, transportation and storage costs are considered as the input variables in the input-oriented DEA model.

Step 3: Study the impact of uncertainty on supply chain efficiency to understand the challenges of the supply chain

We relate the outcomes of the first two steps in order to identify the most important types of uncertainty, i.e. these that impact the performance of the supply chain significantly. This analysis is performed by a Tobit regression since the dependent variable, i.e. the efficiency of individual actors, is a latent variable and is bounded between 0 and 1. These efficiency scores are censored, and the differences are small such that the standard regression technique provides a biased estimate.

3.3.1 Data collection and sampling technique

Both primary and secondary data are collected for understanding the uncertainty in the rice supply chain in the Kyangin and Myanaung townships in the Ayeyarwaddy Region. A purposive and stratified random sampling method is used for primary data collection (Kong, 2015). In this explorative study, the stratification of the sample is solely based upon the role of the respondents in the supply chain in order to discern any differences in the types of uncertainty and its impact between different roles in the supply chain. The sample size is calculated for each stratum in direct proportion[6] to the size of the stratum compared to the (finite) population (cf. Appendix Table 3.A.1) (Judez, 2006). As a result, a sample of 130 farmers, 21 primary collectors, 25 millers, 7 wholesalers, 28 retailers and 4 exporters is selected for conducting the face-to-face interviews. A representative sample for each stratum has been constructed. Appendix Table 3.A.2 shows the socio-economic and demographic characteristics of the respondents, i.e. gender, age, family size, education, working experience, yield, marketed amount of paddy or rice and farm size. For example, 34.62% of the farms have a small size (≤ 2.02 ha), 37.69% have a medium size (> 2.02 ha and ≤ 4.05 ha) and 27.69% have a large size (> 4.05 ha).

[6] This is based on the equation of Yamane (1967), i.e. $n = \frac{N}{1+N(e^2)}$ where N is the population, e^2 is the standard error and n is the sample size.

In-depth and key informant interviews are used to interview sample respondents in order to collect primary data (Umberger, 2014). The questionnaire uses a 7-point Likert scale with end points '1 - strongly disagree' and '7 - strongly agree' to measure the relevant sources of uncertainty. The questionnaire is constructed based on the literature (cf. Table 3.1) and includes different sources of uncertainty with respect to the supply, demand, process, planning and control, competitor, government policy and climate. The questionnaire items are presented in Table 3.1. Moreover, we collect production, marketing and financial data to evaluate the supply chain performance. The secondary data originates from various published sources, from government and other organizations and will be revealed when relevant in discussing the results.

Table 3.1 Questionnaire items of uncertainty factors

Uncertainty Factors	Concept	Aspects of measure-ment	Code	Questions to the actors	References
Supply	Supply uncertainty is related to the unpredictability of the delivery of raw or packed materials in time, in the right amount or according to the right specifications. In this study, paddy is supplied from farmers to rice millers, and milled rice from millers to distributors and so on.	Quantity	SU1	Rice quantity from rice producers is unpredictable.	(van der Vorst, 2000; Li, 2002; Paulraj & Chen, 2007; Thongrattana and Jie, 2009)
		Quality	SU2	Rice quality from rice producers is unpredictable.	
		Time	SU3	Rice producers' delivery time is unpredictable.	
Demand	Demand uncertainty is related to uncertainty about customers' requirements as a combination of unpredictability of demand and product variety (van der Vorst, 2000). Both the international and domestic demand are considered.	Quantity	DU1	The volume of customer demand is difficult to predict.	(Li 2002; Paulraj & Chen 2007; Thongrattana and Jie, 2009)
		Quality	DU2	Customers' rice preference changes over the year.	
		Time	DU3	The lead time of customer order is unpredictable.	
Process	Process uncertainty is related to the production system, including the uncertain ability to produce adequately a particular product or the uncertain availability of sufficient raw materials (van der Vorst, 2000). In this study, the processor refers to any procedure carried out by supply chain members, such as producing, milling, quality control and packing process.	Quantity	PU1	Yield of production or processing (e.g., producing, milling, packing) can vary.	(van der Vorst, 2000; Thongrattana and Jie, 2009)
		Quality	PU2	The quality of rice after processing (e.g., milled, stored) can change.	
		Time	PU3	The throughput time of rice processing can vary.	
Planning and Control	Planning and control uncertainty relates to incomplete information	Quantity	PCU1	Information about stock level of rice and rice production	(van der Vorst, 2000;

	about production, inventory and customer demand (van de Vorst, 2000).			capacity is inaccurate.	Thongratta na and Jie, 2009)
		Time	PCU2	Information about stock level of rice and rice production capacity is not on time.	
			PCU3	Information concerning changes to customer orders cannot be distributed on time.	
Competitor	Competitor uncertainty refers to unpredictable actions by competitors in the competitive markets. This is related to reducing their product price, the time to market or the increasing product quality and variety (Li, 2002). Uncertainty about competitors' actions in the Myanmar rice industry is considered in both domestic and international markets.	Action	CU1	Competitors' actions are unpredictable.	(Li, 2002; Thongratta na and Jie, 2009)
		Domestic market	CU2	Competition in the domestic market is intensifying.	
		Internation al market	CU3	Competition is intensified in different countries.	
Government Policy	Government policy uncertainty includes the unpredictable set of laws, regulations, administrative procedures and policies formally sanctioned by the government, which can affect an organizations' profitability (Badri, Davis and Davis, 2000).	Rice production	GU1	Government policies in rice trading (e.g., FTA, tax) directly affecting your firm are unpredictable.	(Javidan, 1984; Badri et. al., 2000; Bran & Bos, 2005; Thongratta na and Jie, 2009)
		Rice trading	GU2	The grantee price from government regulation is unpredictable.	
		New govern-ment	GU3	New government regulations are	

				introduced unexpectedly.	
Climate	Climate uncertainty is referred to the unpredictable occurrence of serious weather events affecting agricultural lands. These phenomena can lead to rice supply shocks, delays in the time of arrival of paddy to market or transportation disruptions (Cruz et al. 2007).	Drought	CLU1	Drought occurrences affecting firms are unpredictable over the year.	(Curz et al., 2007; Thongrattana and Jie, 2009)
			CLU2	The duration of drought is unpredictable over the year.	
		Flooding	CLU3	Flooding occurrences affecting firms are unpredictable each year.	
			CLU4	The duration of flooding is unpredictable over the years.	

Source: Own compilation based on Thongrattana and Jie (2009)

3.3.2 Research method: Instrument development and factor analysis

This study measures the uncertainty perceived by the different actors in the supply chain and uses a pilot survey to question the farmers. Some previous studies in the rice or food industry (Thongrattana and Jie, 2009; van der Vorst and Beulens, 2002; Bran and Bos, 2005) used the same pilot study and the Q-sort method to check the validity and reliability. For the statistical analysis, non-parametric statistics are applied using SPSS software because of the 7-point Likert scale used for each item and each factor is composed out of a number of items leading to quasi-normal distributed data (Lewis and Harvey, 2001). Descriptive statistics, inferential statistics and factor analysis are applied to investigate the sources of uncertainty. Scale reliability and scale validity tests are conducted before applying factor analysis (Thongrattana and Jie, 2009; van der Vorst and Beulens, 2002; Bran and Bos, 2005). Factor analysis helps to reduce the dimensionality operating on the notion that measurable and observable variables can be reduced to fewer latent variables, which share a common variance and are unobservable (Bartholomew et al., 2011). The factor analysis is conducted using principal component analysis as a method of extraction. Principal Components Analysis is used to extract maximum variance from the dataset with each component and thus reducing a large number of variables into a smaller number of components (Tabachnick and Fidell, 2007).

3.3.3 Research method: Data Envelopment Analysis (DEA)

Charnes, Cooper and Rhodes (1978) originally developed Data Envelopment Analysis (DEA), which is a very powerful service management and benchmarking technique to evaluate nonprofit and public sector organizations. DEA has been widely used to evaluate the firm (i.e. the decision-making unit) performance based on relative efficiency measurements. In this way, this analysis method may contribute to improving the productivity, reducing the costs and increasing the profit margins. In this study, we consider the technical efficiency to measure the performance of the different actors in the rice supply chain. In the literature, distinction is made between the input-oriented and the output-oriented DEA model to measure the efficiency. The input-oriented DEA model minimizes the inputs keeping the outputs at their current level. The output-oriented DEA model maximizes the outputs are maximized keeping the inputs are fixed at their current level (Banker et al., 1984).

3.3.3.1 Technical efficiency (TE) and scale efficiency (SE)

Technical efficiency is defined as the ability of a farm to either produce the maximum feasible output from a given bundle of inputs or to produce the given level of output using the minimum amount of inputs (Basanta et al., 2004). The technical efficiency can be measured under the assumption of *constant returns-to-scale* (CRS), which hypothesizes that the output will change in the same proportion as the inputs are changed (e.g. doubling the inputs will double the output). If the technical efficiency is measured under the assumption of *variable returns-to-scale* (VRS), the production technology is assumed to exhibit increasing and/or decreasing returns to scale (Kumar and Gulti, 2008). The technical efficiency with constant returns-to-scale (TE_{CRS}), which is further referred to as the *overall technical efficiency*, helps to determine inefficiencies due to input/output arrangement as well as the size of operations and is composed out of two components, i.e. the *pure technical efficiency* and the *scale efficiency* (Sharma et al., 1999). The *pure technical efficiency* measure, also called the technical efficiency with variable returns-to-scale (TE_{VRS}), is achieved by estimating the efficient frontier under the assumption of variable returns-to-scale. The pure technical efficiency measures the technical efficiency without considering the scale effect and purely reveals the ability of the business unit to organize its inputs efficiently in the production process. Hence, the *pure technical efficiency* can be used as an index to capture the managerial performance of a decision maker. The ratio of the *overall technical efficiency* vs the *pure technical efficiency* provides the *scale efficiency* (SE). When the *overall technical* efficiency is equal to the *pure technical* efficiency, this business unit is called a scale-efficient unit. *Scale efficiency* expresses whether a firm is operating at its optimal size. The scale efficiency gives notion of the managerial ability to select the optimal resource input size and scale of production to achieve the expected production level (Kumar and Gulti, 2008). The scale inefficiency may be the result from decreasing returns-to-scale (DRS) and increasing returns-to-scale (IRS). Decreasing returns-to-scale implies that a firm is too large to take full advantage of its scale and has a supra-optimum scale size. In contrast, a firm that is experiencing increasing returns-to-scale, is too small for its scale of operations and, thus, operates at sub-optimum scale size. A firm is scale efficient if it operates at constant returns-to-scale (CRS).

Using the DEA model specification, the TE score for a given farm n is obtained by solving the following input-oriented LP problem:

Notation

Sets

I	set of farms (index i)
J	set of inputs (index j)
K	set of outputs (index k)

Parameters

x_{ij}	the amount of input j used on farm i
x_{nj}	the amount of input j used on farm n
y_{ik}	the amount of output k produced on farm i
y_{nk}	the amount of output k produced on farm n

Decision variables

λ_i	the nonnegative weights for I farms
θ_n	the technical efficiency of farm n (a scalar ≤ 1)

Mathematical formulation

$$TE_n = \min \theta_n \tag{3.1}$$

Subject to

$$\sum_{i=1}^{I} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0 \qquad \forall_j \tag{3.2}$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - y_{nk} \geq 0 \qquad \forall_k \tag{3.3}$$

$$\sum_{i=1}^{I} \lambda_i = 1 \tag{3.4}$$

$$\lambda_i \geq 0 \tag{3.5}$$

The objective function (eq. 1) of the input-oriented DEA model minimizes the inputs while the outputs are kept at their current levels. If θ_n is equal to 1, the business unit is technically efficient. When θ_n is smaller than 1, the business unit is technically inefficient with the level of inefficiency equal to 1 – TE_n (Coelli, 1995). Equation (2) is the input constraint formulated for every input *j*. This constraint stipulates that the input used by farm *n*, weighted by its efficiency level θ_n, must exceed or be equal to a weighted combination of inputs used by the other farms. Equation (3) is the output constraint formulated for every output *k*. This constraint stipulates that the output obtained by farm *n* must be lower than or equal to the weighted combination of outputs obtained by the other farms. Equation (3.4) sets the sum of all weights given to the other farms is equal to 1 and ensures that the technical efficiency TE_n in equation (3.1) is calculated under the assumption of variable returns-to-scale (VRS) (Coelli, 1995). Model (3.1)-(3.5) is the formulation proposed by Banker, Charnes, and Cooper (1984) and calculates the pure technical efficiency ($TE_n = TE_{VRS_n}$). When equation (3.4) is omitted, constant returns-to-scale (CRS) are assumed and the model reflects the formulation proposed by Charnes, Cooper, and Rhodes (1978) to calculate the overall technical efficiency ($TE_n = TE_{CRS_n}$).

The scale efficiency for farm *n* (SE_n) can be calculated by the following equation:

$$SE_n = \frac{TE_{CRS_n}}{TE_{VRS_n}} \tag{3.6}$$

where, TE_{CRS_n} = technical efficiency under CRS assumption for farm *n* and TE_{VRS_n} = technical efficiency under VRS assumption for farm *n*.

3.3.4 Research method: Tobit regression model

The Tobit regression model is used to perform a regression analysis to determine the significant uncertainty factors that hinder the rice production efficiency, which is obtained via DEA. Tobit analysis assumes that the dependent variable has a number of factors clustered at a limiting value, usually zero (Tobin, 1958). Hence, the following regression model is employed, i.e.

$$y_i^* = x_i\beta_i + \mu_i \quad i = 1, 2, \ldots, n \tag{3.7}$$

$$y_i = y_i^* \; if \;\; y_i^* < 0 \tag{3.8}$$

$$y_i = 0, otherwise \tag{3.9}$$

where

$\mu_i \sim N(0, \sigma^2)$	the error term
x_i	explanatory variables
β_i	estimated parameter coefficients
y_i^*	a latent variable
y_i	the efficiency scores obtained via the DEA model

3.4 Results and Discussion

In this section, we present the results of this study. Section 3.4.1 discusses the uncertainty as perceived by the actors in the rice supply chain and investigates the most important uncertainty factors in the rice supply chain by using factor analysis. In Section 3.4.2, we measure the rice supply chain efficiency as a measurement of supply chain performance by applying a DEA approach. In Section 3.4.3, we determine the impact of uncertainty factors on the supply chain efficiency by conducting a Tobit regression analysis.

3.4.1 Uncertainty factors in the rice supply chain

3.4.1.1 Descriptive statistics of the uncertain factors in the rice supply chain

Table 3.2 displays the perceived uncertainty factors in the rice supply chain in the Ayeyarwaddy Region, Myanmar. The actor responses are sub-divided into three groups, i.e., "Disagree" (Scale 1-3)", "Neutral" (Scale 4)" and "Agree" (Scale 5-7)" for the 7-point Likert scale. According to Table 3.2, the rice supply chain actors agree on average on all the uncertainty items since all averages are higher than 4. Hence, the actors in the rice supply chain encounter the different types of uncertainty observed in the literature. There are, however, significant differences in the uncertainty perception between different individuals per questionnaire item ($p = 0.000$ for each item). The item "*information about stock level of rice and rice production capacity is not on time* (PCU2)" related to the planning and control uncertainty has the lowest mean value of 4.08. The highest mean perceived uncertainty is observed for the items "*the flooding occurrence affecting firms are unpredictable each year* (CLU3) and "*the duration of the flooding is unpredictable over the years* (CLU4)" related to the climate uncertainty. This is in contrast to the study of Thongrattana and Jie (2009), which observed a higher uncertainty for government policy.

Table 3.2 Descriptive statistics of the uncertain factors in the rice supply chain (N=215)

Items	Code	Disagree (Scale 1-3)	Neutral (Scale 4)	Agree (Scale 5-7)	Mean	Std. Deviation
Supply Uncertainty (SU)	SU1	15.82	3.72	80.46	5.66	1.595
	SU2	17.22	2.79	79.99	5.53	1.795
	SU3	17.68	4.19	78.14	5.30	1.776
Demand Uncertainty (DU)	DU1	7.91	4.19	87.9	5.79	1.312
	DU2	8.84	4.65	86.51	5.73	1.280
	DU3	4.66	14.42	80.93	5.47	1.126
Process Uncertainty (PU)	PU1	8.84	9.30	81.87	5.47	1.314
	PU2	6.06	13.95	80.00	5.50	1.322
	PU3	8.38	14.88	76.75	5.22	1.382
Planning and Control Uncertainty (PCU)	PCU1	43.71	13.02	43.27	4.12	1.861
	PCU2	36.74	13.02	50.24	4.08	1.840
	PCU3	34.88	13.95	51.17	4.14	1.781
Competitor Uncertainty (CU)	CU1	15.82	9.77	74.41	5.17	1.629
	CU2	21.40	10.23	68.37	4.82	1.846
	CU3	21.86	8.84	69.31	4.84	1.818
Government Policy Uncertainty (GU)	GU1	14.88	8.37	76.74	5.40	1.745
	GU2	12.56	9.77	77.68	5.44	1.642
	GU3	24.18	13.95	61.85	4.84	1.792
Climate Uncertainty (CLU)	CLU1	10.70	4.65	84.64	5.80	1.504
	CLU2	12.56	4.65	82.79	5.73	1.598
	CLU3	7.91	3.26	88.84	6.00	1.365
	CLU4	8.38	3.72	87.91	6.00	1.399

Source: Own data (2017) and SPSS

3.4.1.2 Relevant uncertainty factors

According to the results of the Principal Component Analysis (cf. Table 3.3), 74.65% of the overall variance in the observed variables can be explained by all uncertainty factors together listed in Table 3.1. Climate uncertainty explains the largest part of the overall variance (14.86%) followed by planning and control uncertainty (12.30%) and competitor uncertainty (10.88%). The findings of this study are clear evidence that the actors in the rice supply chain in the Ayeyarwaddy Region in Myanmar face a high level of climate, planning and control, and competitor uncertainty. Our findings confirm the results of Thongrattana and Jie (2009), Miller (1993) and Lewis & Harvey (2001) showing the impact of the planning and control, competitor's behavior, government policy and climate uncertainty on the rice supply chain.

The unpredictable climate is an essential component because it effects the agricultural and socio-economic system both directly and indirectly, especially in developing countries. The agricultural system of the developing countries is mostly dependent on rainfall because of the lack of technological adaptations (Darwin et al., 1995; Ogallo et al., 2000).

The second important component is planning and control uncertainty referring to the unavailability of "on time and accurate production and inventory information". This results from the fact that information technology is not appropriately implemented in the rice industry of Myanmar. The importance of acquiring appropriate information is self-evident. The collection of appropriate information about the customer demand, sales forecasts order status, inventory levels, capacity availability, lead times and quality is critical to the effective functioning of a supply chain. Timely information dissemination affects a supply chain's ability to cope with uncertainty and faster transmission is better for supply chain members in satisfying both their own differentiated goals and the supply chain's interdependent goals. The result is consistent with the findings of Mason-Jones and Towill (1998). They indicated the importance of planning and control uncertainty in the rice supply chain, which is concerned with the capability of an organization to use information flow and decisions to transform customer orders into a production plan and raw material requirements. This finding also confirms the study of Quesada et al. (2012), which investigated the supply chain of the pallet industry in the United States.

The high level of unpredictability of competitor's behaviour results from the severe competition for the retailers on the domestic markets and the intensive competition with other rice production countries, which introduce rice at a low price. The perceived high uncertainty in the government policy gives proof that the government policy in developing countries is turbulent and unpredictable (Badri et al., 2000).

Table 3.3 Structure of Rotated Component Matrix for the rice supply chain (N=215)

Types of uncertainty	Code	Component						
		1	2	3	4	5	6	7
Climate Uncertainty (CLU)	CLU3	0.890						
	CLU2	0.889						
	CLU4	0.887						
	CLU1	0.830						
Planning and Control Uncertainty (PCU)	PCU2		0.953					
	PCU3		0.950					
	PCU1		0.833					
Competitor Uncertainty (CU)	CU2			0.952				
	CU3			0.944				
	CU1			0.668				
Government Policy Uncertainty (GU)	GU1				0.825			
	GU3				0.800			
	GU2				0.758			
Process Uncertainty (PU)	PU2					0.824		
	PU1					0.771		
	PU3					0.714		
Supply Uncertainty (SU)	SU1						0.840	
	SU2						0.808	
	SU3						0.678	
Demand Uncertainty (DU)	DU2							0.832
	DU3							0.727
	DU1							0.700
Eigen value		3.270	2.706	2.393	2.085	2.004	1.989	1.978
% of Variance		14.864	12.298	10.879	9.478	9.108	9.039	8.989
Cumulative % of variance		14.864	27.161	38.041	47.519	56.627	65.667	74.656

Extraction Method: Principal Component Analysis[7]
Rotation Method: Varimax with Kaiser Normalization.
Source: Own data (2017) and SPSS

[7] Before we conduct a principal component analysis or factor analysis, we must verify if the necessary conditions are fulfilled:

- To measure the *scale reliability*, we calculate the correlation matrix of the 22 uncertainty factors and the determinant. Since the determinant is different from zero, the factor analysis may be completed. Moreover, in order to measure scale reliability of the questionnaire, Cronbach's alpha is used (Bryman, 2003; Haire et al., 1995). The value of Cronbach's alpha is accepted for an exploratory study if it exceeds 0.7 (Nunnally, 1967). The Cronbach's alpha of these scales ranges from 0.710 to 0.922. No items are deleted in the analysis.
- The *scale validity* is measured by the Kaiser-Meyer-Olkin Measure (KMO) and Bartlett's Test. The result for the Kaiser-Meyer-Olkin Measure (KMO) is acceptable since it is larger than 0.6 (Kaiser, 1974), and Bartlett's Test is highly significant at $p<0.000$. Scale validity indicates the construct is able to measure accurately the concept under study (Haire et al., 1995).
- The *construct validity* is measured by explanatory factory analysis (EFA) (Haire et al., 1995). All components have Eigenvalues larger than 1, which confirms the construct validity.

3.4.1.3 Comparisons of uncertainty perception among the rice supply chain actors

In this section, we investigate the relevance of the uncertainty factors for each of the supply chain actors since different parties may encounter different types of uncertainty. The results of the descriptive and comparison analysis are carried out using a non-parametric Kruskal-Wallis test in Appendix Table 3.A.3 to 3.A.9[8].

The exporters perceive significantly lower supply uncertainty with respect to the quantity delivered by producers ($\alpha = 0.05$) and the delivery time ($\alpha = 0.1$) because of aggregation effects and the fact that exporters typically carry out different roles in the rice supply chain, i.e. farming, milling and wholesaling (cf. Appendix 3.A.3). The wholesalers perceive a significantly higher demand and supply uncertainty because of their distributor role in the supply chain. They find it very difficult to predict the customer demand ($\alpha = 0.05$) (cf. Appendix 3.A.4) because of the complexity of the sales network with many retailers and wholesalers. The higher supply uncertainty is related to the unpredictable quantity supplied and delivery time. Farmers perceive a significantly lower competitor uncertainty since they are more aware of their competitors' actions ($\alpha = 0.05$) (cf. Appendix 3.A.7). Farmers witness easily other farmers' strategies applied in their paddy fields within the same village and they even share knowledge about their production techniques. An analysis of the uncertainty resulting from the government actions between different parties reveals (Appendix 3.A.8) that wholesalers suffer from the high volatility in the grantee price ($\alpha = 0.05$). Moreover, exporters encounter significantly less uncertainty resulting from the unexpected introduction of new government regulations compared to other actors ($\alpha = 0.01$) as they are operating on the international market. For the other types of uncertainty (i.e. the processing uncertainty, the planning and control uncertainty and the climate uncertainty), there are no significant differences between the different actors (cf. Appendix 3.A.5, cf. Appendix 3.A.6 and cf. Appendix 3.A.9).

[8] To compare the results between different actors, we apply the non-parametric Kruskal-Wallis test to find significant differences.

3.4.2 Efficiency performance of the rice supply chain

3.4.2.1 Descriptive statistics of the variables

In this section, we investigate the supply chain efficiency to measure the supply chain performance. We measure the overall technical efficiency, pure technical efficiency and scale efficiency for the entire supply chain, i.e. farmers (production stage), millers (processing stage) and distributors such as wholesalers, retailers and exporters (distribution stage) are comprised in the analysis. In this section, we do not consider the primary collectors to analyse the efficiency measures because they do not have any inputs and all primary collectors receive the same fee from the millers for buying paddy. A summary of the values of the key variables used in the DEA model is presented in Table 3.4, 3.5 and 3.6. We consider the marketed amount of paddy as the output variable. The production, financial, transportation and storage costs are considered as the input variables in the input-oriented DEA model. The average marketed amount of paddy per year for the farmers is 6500 kilograms. The hired labour cost for farmers (on average 89.72 MMK/kg) is far higher compared to the other costs. The mean marketed amount of rice per year for the millers is 1088.17 thousand kilograms and ranges from 12.68 to 3793.48 thousand kilograms (cf. Table 3.5). The transportation cost (on average 21.44 MMK/kg) embodies the highest cost for the millers. The distributors deliver 52189.97 thousand kilograms of rice on average with a range between 1.38 thousand kilograms to 1700000 thousand kilograms (cf. Table 3.6). The transportation cost (on average 6.94 MMK/kg) is slightly higher than the other costs for distributors.

Table 3.4 Descriptive statistics of the output and input variables of the rice farmers (N=130)

Variables	Unit	Mean	Minimum	Maximum	Std. Deviation
Output variable					
Marketed amount	000’ kg	6.50	0.29	31.04	5.98
Input variables					
Production cost (Total)					
-Material cost	MMK/kg	58.38	12.89	287.08	38.84
-Family labor cost	MMK/kg	54.46	2.83	218.99	35.38
-Hired labor cost	MMK/kg	89.72	3.87	359.99	51.50
Financial cost	MMK/kg	7.41	2.43	32.35	4.18

Note: We assumed 1USD = 1350 MMK
Source: Own survey (2017)

Table 3.5 Descriptive statistics of the output and input variables of the rice millers (N=25)

Variables	Unit	Mean	Minimum	Maximum	Std. Deviation
Output variable					
Marketed amount	000’ kg	1088.17	12.68	3793.48	1132.99
Input variables					
Production cost	MMK/kg	5.66	0.53	32.79	8.66
Financial cost	MMK/kg	5.14	2.31	14.74	2.48
Transportation cost	MMK/kg	21.44	9.08	36.84	8.66
Storage cost	MMK/kg	6.28	3.06	11.22	2.77

Note: We assumed 1USD = 1350 MMK
Source: Own survey (2017)

Table 3.6 Descriptive statistics of the output and input variables of the rice distributors (N=39)

Variables	Unit	Mean	Minimum	Maximum	Std. Deviation
Output variable					
Marketed amount	000' kg	52189.97	1.38	1700000.00	273008.49
Input variables					
Production cost	MMK/kg	2.21	0.00	24.00	6.76
Financial cost	MMK/kg	5.62	0.87	27.78	7.51
Transportation cost	MMK/kg	6.94	2.04	13.78	2.60
Storage cost	MMK/kg	1.92	0.94	9.00	1.96

Note: We assumed 1USD = 1350 MMK
Source: Own survey (2017)

3.4.2.2 Technical efficiency and scale efficiency

Table 3.7 displays the results derived from the DEA model (1)-(5) and the scale efficiency (cf. equation (6)) for the different actors and the global rice supply chain. The overall technical efficiency of the farmers equals on average 0.225 and ranges between 0.002 and 1. Hence, the technical efficiency of farmers can be increased by 77.5% on average. The farmers do not efficiently manage their input costs. They do not obtain the maximal possible output given their input costs. According to the results, only a small percentage (2.31%) obtains a high overall technical efficiency level (0.91 to 1.00). 10% of the farmers achieve an acceptable technical efficiency level (range 0.51-0.90). Most of the farmers (87.70%) have an inferior technical efficiency level smaller than or equal to 0.5. Hence, most of the farmers are inefficient and are unable to produce according to their maximum potential given their input costs. The mean pure technical efficiency is 0.610 and the mean scale efficiency is 0.332. The mean scale efficiency is lower than the mean pure technical efficiency, which implies that rice farms should improve firstly the allocation of their input costs to achieve a better pure technical efficiency and then try to improve their operational scale to upgrade the scale efficiency in order to boost the overall technical efficiency. No less than 98.46% of the farms have increasing returns-to-scale (IRS), i.e. if these farms can expand their production scale they should be able to improve the overall operational efficiency. Only 1.54% of the farmers have constant returns to scale (CRS) which means these farmers operate in the desired scale and there is no need for any improvement.

The millers have on average a technical efficiency of 41.3%. About 20% of the millers reach a high technical efficiency score between 0.91 and 1. 20% of the millers have an acceptable overall technical efficiency score between 0.51 and 0.90 and 60% of the millers have an efficiency level smaller than or equal to 0.5. The average pure technical efficiency (0.873) is larger than the average scale efficiency (0.455) for this processing stage. Hence, millers can reduce their operating costs of the input mix to improve their pure technical efficiency and expand their scale of operations in order to enhance the overall efficiency. The mean overall technical, pure technical and scale efficiency scores of this study are lower than those of the millers in Thailand and Taiwan (Wongkeawchan et al., 2004). About 84% of all millers have increasing returns-to-scale (IRS), which indicates that they are able to improve their overall operational efficiency if they can expand their production scale. Another 16% of the millers are in the stage of constant returns-to-scale (CRS). These firms do not have to upgrade the scale of their firm.

The overall technical efficiency of the distributors is on average 0.125 which implies that most distributors have a huge improvement potential. Only 7.69% of the distributors reach a high overall technical efficiency level ranging from 0.81 to 1.00. The majority of the distributors (92.31%), however, obtain an efficiency score smaller than or equal to 0.5. The mean pure technical efficiency is 0.820 and is much larger than the scale efficiency (0.145). The distributors should try to improve the efficient use of the inputs and then adjust their operational scale. The majority of the distributors (94.87%) have increasing returns-to-scale (IRS), which suggests that most distributors need to upgrade the scale of their organization.

The technical efficiency amounts 0.229 on average for the global rice supply chain, which is low. This value shows a large improvement potential of 77.1%. The majority of the actors (85.05%) have an overall technical efficiency level smaller than or equal to 0.5. The mean pure technical efficiency is only 0.686 due to the inappropriate management of the inputs. The mean scale efficiency is 0.310, which is very low due to the fact that most actors are operating in a smaller-than-optimal scale. The majority of the supply chain actors (95.88%) have increasing returns-to-scale (IRS) suggesting they would improve their efficiency if they can expand their production scale. Only 4.12% of the supply chain actors operate conform to their optimal scale.

Table 3.7 Percentage distribution of the technical and scale efficiency index for the actors and the global rice supply chain

Efficiency Level	Farmers (N=130)			Millers (N=25)			Distributors (N=39)			Global Supply Chain (N=194)		
	TE_{CRS} (%)	TE_{VRS} (%)	SE (%)	TE_{CRS} (%)	TE_{VRS} (%)	SE (%)	TE_{CRS} (%)	TE_{VRS} (%)	SE (%)	TE_{CRS} (%)	TE_{VRS} (%)	SE (%)
0.00 – 0.10	39.23	0.00	19.23	24.00	0.00	20.00	79.49	0.00	71.79	45.36	0.00	29.90
0.11 – 0.20	22.31	3.85	24.62	24.00	0.00	12.00	7.69	0.00	10.26	19.59	2.58	20.10
0.21 – 0.30	13.08	3.08	13.85	0.00	0.00	16.00	0.00	2.56	2.56	8.76	2.58	11.86
0.31 – 0.40	8.46	4.62	10.00	12.00	0.00	8.00	5.13	5.13	2.56	8.25	4.12	8.25
0.41 – 0.50	4.62	13.08	6.15	0.00	4.00	0.00	0.00	0.00	5.13	3.09	9.28	5.15
0.51 – 0.60	5.38	30.77	8.46	12.00	8.00	12.00	0.00	0.00	0.00	5.15	21.65	7.22
0.61 – 0.70	2.31	16.92	6.15	4.00	12.00	4.00	0.00	12.82	0.00	2.06	15.46	4.64
0.71 – 0.80	2.31	10.77	3.85	4.00	4.00	4.00	0.00	20.51	0.00	2.06	11.86	3.09
0.81 – 0.90	0.00	6.15	3.85	0.00	8.00	4.00	2.56	17.95	2.56	0.52	8.76	3.61
0.91 – 1.00	2.31	10.77	3.85	20.00	64.00	20.00	5.13	41.03	5.13	5.15	23.71	6.19
Mean	0.225	0.610	0.332	0.413	0.873	0.455	0.125	0.820	0.145	0.229	0.686	0.310
Minimum	0.002	0.109	0.014	0.008	0.485	0.009	0.001	0.290	0.001	0.001	0.109	0.001
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IRS			98.46%			84.00%			94.87%			95.88%
DRS			0.00%			0.00%			0.00%			0.00%
CRS			1.54%			16.00%			5.13%			4.12%

Source: Own survey (2017) and DEAP 2.1

3.4.3 The impact of uncertainty on of the rice supply chain performance

In this section, we examine if the identified environmental uncertainty factors impact the operational efficiency based on a Tobit regression model as suggested by Coelli and Basttese (1996). To that purpose, the Tobit model is applied to regress the efficiency scores on the uncertainty factors since the efficiencies vary from 0 to 1. The Tobit regression analysis is conducted in Eviews 9. Table 3.8 describes the summary statistics of the uncertainty factors for which the impact on the rice supply chain efficiency is verified. The dependent variables are the efficiency scores, i.e. the overall technical efficiency, the pure technical efficiency and the scale efficiency. The independent variables are the 7 sources of uncertainty factors, i.e. supply, demand, process, planning and control, competitive, government policy and climate uncertainty. This analysis is performed for the farmers (production stage), the millers (processing stage), the distributors, i.e. the wholesalers, retailers and exporters (distribution stage) and the entire supply chain.

The results of the Tobit regression analysis for the farmers are presented in Table 3.9. The Tobit regression coefficients indicate the directional relationship between efficiency and the independent variables. Table 3.9 reveals that the planning and control uncertainty has a negative and significant impact on all efficiency measures of the farmers. The overall technical, pure technical and scale efficiency is reduced when the uncertainty in planning and control increases. Information is crucial to operational planning and control. The higher the quality of information input, the higher the quality of managerial decision making (Gorry and Morton, 1989). In-depth interviews learned that the most efficient farmers use information to wait for a higher paddy price and increase their stock level capacity. In this way, these farmers do not have to sell their paddy at a lower price immediately after harvesting. The climate uncertainty has a negative and significant impact on the overall technical efficiency and pure technical efficiency. The technical efficiency of the farms decreases significantly as a result from the high climate uncertainty. This study confirms the result of Muhammad et al. (2012). The effects of uncertain climatic conditions on rice production lead to large inefficiencies and as a result a significant amount of paddy is lost. In order to reduce the climate uncertainty, the most efficient farmers use some mitigation strategies by proactively changing their sowing time to overcome the uneven rain at the harvest time, using cushions to prevent rain to impact the paddy harvest piles when harvesting, threshing, drying and transporting the paddy. These best practices related to cultivation and post-harvesting techniques and climate mitigation strategies together with the knowledge transfer of new technologies should be widespread via better extension services (Naswem et al., 2016). Moreover, crop insurance is potentially a very effective climate mitigation strategy for the farmers in the study area that can be ensured by the government or private partners. By spreading risk, this strategy can buffer the financial implications of unexpected crop failure following climate uncertainty and may change the decision-making behaviour of farms and improve their efficiency level. According to Di Falco (2014), Olivier and Charles (2010) and Ambarawati et al. (2018), agricultural or crop insurance has been an important tool at the farm level in different agricultural supply chains to mitigate the climate or natural disaster uncertainty and has also been implemented in many developing countries including India and Thailand. The government and private partners are responsible to secure the availability of high-quality production inputs (seeds, fertilizers, chemicals). Early maturing, drought resistant and flood resistant varieties of rice should be made available to farmers to enable them to cope with the vagaries of the climate (Naswem et al., 2016).

The efficient operation of millers is hampered significantly by process uncertainty for all types of efficiency measures (cf. Table 3.9). This result confirms the study of Thongrattana (2012), Childerhouse and Towill (2004), Bhatnagar and Sohal (2005), van der Vorst (2000) and Davis (1993). In-depth interviews learned that the most efficient millers in the study area manage this type of uncertainty in a reactive manner by hiring skilful mechanics to repair their broken machines immediately. Another, more preferred approach is to install labour flexibility and machine flexibility to mitigate process uncertainty proactively, i.e. multi-skilled workers are trained and/or general purpose machines, equipment and technologies are implemented to increase the process flexibility (Miller, 1992; Sawhney, 2006; Ulrich, 1995). Moreover, the planning and control uncertainty has a negative and significant impact on the overall technical efficiency and the scale efficiency of the rice millers. The most efficient millers have sufficient storage capacity to meet the changes in customer orders. To prevent the deterioration of the rice quality during the storage time, the millers check the rice quality on a regular basis. The availability of a computer-based information system, shared between different supply chain partners, may provide real-time and accurate information and transparency and will reduce the planning and control uncertainty along the supply chain (Prater, 2005). The climate uncertainty has also a significant and negative impact on the overall technical efficiency and scale efficiency of the millers. This is primarily caused by the fact that some millers are also farmers and produce paddy. Climate uncertainty may cause a rice shortage and inferior rice quality. In order to reduce the uncertainty and to improve their efficiency, the millers perform a quality inspection and adapt their price according to the rice quality. In addition, because of extreme weather conditions, the transportation of paddy (from the farmers) or rice (towards the customers) is impeded because of road destructions leading to customer delays. Paddy and rice reserves help to reduce these negative effects resulting from climate conditions. However, the efficiency of millers is significantly reduced as they cannot distribute the processed rice on time. The government needs to invest in the existing road infrastructure in collaboration with the private sector to increase the access to the markets and avoid inefficiencies in transport and logistics (Linn and Maenhout, 2018a).

The results of the Tobit regression analysis for the rice distributors are also presented in Table 4.8. The demand uncertainty has a negative and significant impact on all efficiency measures, i.e. a higher demand uncertainty can significantly lower the efficiency. The demand uncertainty arises from the complexity of the sales network in the distribution system i.e. many retailers and wholesalers involved in the rice supply chain and the unpredictable domestic and international demand and product variety. As a result of the demand uncertainty, the rice distributors have difficulties to organize their operations efficiently, i.e. to use the right input resource mix and to operate at the right scale. In order to reduce this uncertainty, the most efficient distributor parties have maintained multiple suppliers, which will guarantee availability to improve supply flexibility to be able to meet the necessities of their customers. According to Tang and Tomlin (2008), flexible procurement contracts can provide supply flexibility, ensure stability for the supplier, and help the buyer respond to demand fluctuations. The climate uncertainty also has a negative and significant impact on the overall technical efficiency and scale efficiency of the distributors. Accurate weather information may help them to better organise the rice distribution to other regions and to foreign countries.

Finally, we discuss the results of Tobit regression analysis for the global rice supply chain (cf. Table 3.9). Previous results revealed that the different actors in different stages of the rice supply chain face different types of uncertainty, each related to their role in the rice supply chain. However, we observe that global supply chain is principally impacted by the planning and control uncertainty and the climate uncertainty, which were mainly observed as relevant sources of uncertainty in the early stages of the global rice supply chain and resonates throughout the entire supply chain. The planning and control uncertainty has a negative and significant impact on the overall technical efficiency and scale efficiency, i.e. a higher uncertainty in planning and control leads to a decrease in the efficiency of the supply chain. This result does not confirm the study of Thongrattana (2012). Prater (2005) recognizes that sharing a computerised information system between supply chain partners, enables a better and faster information flow and will reduce the planning and control uncertainty along the supply chain. In this regard, the Myanmar Rice Federation (MRF) encourages actors to establish cooperatives by organizing trainings, meetings and conferences. Setting up collaborations enables the integration of the supply chain members, i.e. all members of the chain 'acts as one', will lead to reductions in process, supply, demand and control uncertainty (Simangunsong, 2012). The climate uncertainty negatively impacts the overall and pure technical efficiency of the global rice supply chain. This result is consistent with the finding of Nyamah et al. (2017) but does not confirm the result of Thongrattana (2012). According to Kleindorfer and Saad (2005), Tang (2006) and Ritchie and Brindley (2007) insurance is one of the most common strategies for mitigating uncertainty or risk, and hence lessens the severity of disruptions such as natural disasters or weather-related events on supply chain activities.

Table 3.8 Descriptive statistics of uncertainty variables of the supply chain

Variables	Unit	Farmers (N=130)		Millers (N=25)		Distributors (N=39)		Global supply chain (N=194)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Supply uncertainty (SU)	Number	5.59	1-7	5.64	2-7	5.54	1-7	5.59	1-7
Demand uncertainty (DU)	Number	5.58	2-7	5.84	2-7	5.87	1-7	5.67	1-7
Process uncertainty (PU)	Number	5.72	2-7	5.80	3-7	5.59	3-7	5.70	2-7
Planning and control uncertainty (PCU)	Number	4.06	1-6	4.00	3-5	4.14	2-5	4.07	1-7
Competitive uncertainty (CU)	Number	4.63	1-7	5.24	2-7	5.26	2-7	4.84	1-7
Government uncertainty (GU)	Number	5.05	1-7	5.48	2-7	5.69	1-7	5.3	1-7
Climate uncertainty (CLU)	Number	5.92	2-7	6.04	2-7	6.03	1-7	5.95	1-7

Source: Own survey (2017)

Table 3.9 Results of Tobit regression coefficients for all different actors and the global supply chain

Independent Variables	Farmers (N=130)			Millers (N=25)			Distributors (N=39)			Global supply chain (N=194)		
	TE_{CRS}	TE_{VRS}	SE	TE_{CRS}	TE_{VRS}	SE	TE_{CRS}	TE_{VRS}	SE	TE_{CRS}	TE_{VRS}	SE
Constant	0.9696***	1.0383***	1.0949***	2.0561***	1.6660***	1.6607***	1.3543***	1.1184***	1.3112***	1.1305***	0.8348***	1.2432***
	(0.1508)	(0.1483)	(0.1847)	(0.4420)	(0.3301)	(0.4275)	(0.2428)	(0.2252)	(0.2560)	(0.1346)	(0.1344)	(0.1526)
Supply uncertainty	-0.0195	-0.0151	-0.0224	0.0469	0.0218	0.0439	0.0072	0.0311	-0.0073	-0.0034	-0.0008	-0.0060
	(0.0133)	(0.0131)	(0.0163)	(0.0346)	(-0.0573)	(0.0312)	(0.0204)	(0.0189)	(0.0215)	(0.0123)	(0.0121)	(0.0140)
Demand uncertainty	-0.0279	0.0027	-0.0276	-0.0063	-0.0573	-0.0449	-0.1026***	-0.0715**	-0.0887**	-0.0220	0.0168	-0.0203
	(0.0173)	(0.0171)	(0.0212)	(0.0408)	(0.0352)	(0.0456)	(0.0379)	(0.0351)	(0.0399)	(0.0169)	(0.0157)	(0.0191)
Processing uncertainty	0.0082	0.0022	0.0109	-0.1940***	-0.1276***	-0.1658**	0.0610	0.0255	0.0584	-0.0072	-0.0074	-0.0015
	(0.0186)	(0.0183)	(0.0228)	(0.0697)	(0.0541)	(0.0701)	(0.0320)	(0.0297)	(0.0338)	(0.0174)	(0.0168)	(0.0197)
Planning and control uncertainty	-0.0435***	-0.0244**	-0.0516***	-0.0585***	-0.0253***	-0.0711***	-0.0103	0.0104	-0.0045	-0.0421***	-0.0161	-0.0497***
	(0.0104)	(0.0102)	(0.0127)	(0.0188)	(0.0153)	(0.0198)	(0.0208)	(0.0193)	(0.0219)	(0.0097)	(0.0095)	(0.0110)
Competitive uncertainty	-0.0115	-0.0112	-0.0118	0.0056	0.0270	0.0127	-0.0052	-0.0356	0.0058	-0.0123	0.0049	-0.0152
	(0.0104)	(0.0103)	(0.0128)	(0.0272)	(0.0224)	(0.0290)	(0.0263)	(0.0244)	(0.0277)	(0.0103)	(0.0100)	(0.0117)
Government policy uncertainty	-0.0167	0.0112	-0.0297	-0.0392	0.0052	-0.0518	-0.0142	0.0210	-0.0238	-0.0095	0.0049	-0.0228
	(0.0120)	(0.0118)	(0.0147)	(0.0381)	(0.0305)	(0.0395)	(0.0289)	(0.0258)	(0.0294)	(0.0118)	(0.0111)	(0.0133)
Climate uncertainty	-0.0374***	-0.0478***	-0.0240	-0.0999***	0.0151	-0.0860**	-0.1417***	-0.0285	-0.1339***	-0.0738***	-0.0287***	-0.0644***
	(0.0142)	(0.0139)	(0.0174)	(0.0406)	(0.0315)	(0.0408)	(0.0289)	(0.0268)	(0.0305)	(0.0135)	(0.0129)	(0.0153)
LR test	36.5817***	19.9360***	31.5090***	35.1754***	11.2776	32.1591***	29.9492***	9.3101	27.6637***	60.9329***	14.2274***	55.1842***

Dependent variables are TE_{CRS} index, TE_{VRS} index and SE index.
Note: Figures in the parentheses are standard error.
** = significant at 5% level and *** = significant at 1% level.
Source: Own survey (2017) and Eviews 9.

3.5 Conclusion and Recommendations

3.5.1 Conclusion

In this study, we determined the major sources of environmental uncertainty impacting the rice supply chain in the Ayeyarwaddy Region, Myanmar. There are different types of actors in the rice value chain i.e. farmers, rice millers, wholesalers, retailers and exporters and we investigate how uncertainty affects the decision-making performance of these actors. To that purpose, we applied a three-step methodology. First, we have conducted an empirical survey and applied an exploratory factor analysis to identify the sources of uncertainty perceived by the different actors in the rice supply chain. The environmental uncertainty and its associated factors are defined in terms of perception of the respondents given the role of individuals in the decision-making process. All the seven considered uncertainty factors are present; however, the climate uncertainty is the most important factor in the rice supply chain followed by planning and control uncertainty and competitor uncertainty. Second, we measure the rice supply chain efficiency to assess the supply chain performance using Data Envelopment Analysis (DEA). Based on his perception, the decision maker will take relevant strategic and operational decisions, i.e. he will determine the mix of inputs to maximize his output level and his scale of operations. The mean performance of the entire rice supply chain is by a low overall technical efficiency score, which is especially caused by the very low scale efficiency for all actors. Therefore, the majority of the business units need to expand their operating size. Moreover, their market knowledge and the method to collect accurate market information should be improved to reduce their input costs. Third, we study the significance of the impact of the identified sources of uncertainty on the supply chain efficiency to find the most important types of uncertainty. Each type of actor suffers from specific uncertainty sources related to their role in the supply chain. Farmers face climate uncertainty and uncertainty in planning and control. The millers in particular suffer significantly from processing uncertainty. Distributors face the adverse effect of demand uncertainty. The climate uncertainty and planning and control uncertainty, which are both in particular present in the early production stages of the supply chain, have a negative and significant impact on the different types of efficiency leading to the poor performance of the entire supply chain.

3.5.2 Recommendations

The described sources of uncertainty highlight the array of key issues that must be resolved to upgrade the performance of the rice supply chain. The observed low operational efficiency of the studied rice supply chain shows that the actors do not make use of resources in the best possible way and can significantly improve the way their limited resources are allocated. To that purpose, uncertainty should be mitigated, especially the uncertainty regarding the climate and the planning and control. However, priorities should be set to accomplish a feasible and gradual progress to improve the competitiveness of the rice sector in Myanmar. Future research should give more insights in each of the proposed mitigation strategies and their actual impact on the rice supply chain in Myanmar.

First, public awareness of the impact of climate conditions on the agricultural production systems deserves priority consideration and mitigating technologies must be developed, which will require increased public and private investment. An appropriate financial insurance mechanism should be implemented by the government and private partners for all rice supply chain actors and in particular for the farmers. Further research should indicate the most suitable insurance program, i.e. a weather-based crop insurance program or an area-based crop insurance program. In this way, the actors and especially the farmers should be better able to use their resources more efficiently to maximize their output level as a result from the reduced level of uncertainty.

Second, farmers and other roles in the supply chain should organize themselves in cooperatives, which implies a horizontal and vertical integration in the supply chain. In the era of intense global trade, it is essential for firms to exploit the benefits associated with sharing supply chain information to improve the supply chain performance. Moreover, the majority of the current rice companies in the supply chain are too small and via setting up cooperatives they will expand their size. In this way, the bargaining power of actors on the national and international market will increase and price fluctuations will be less volatile and more accurate market information will be obtained. These collaborations support the installment of computerized information sharing systems and decision support systems, which will reduce planning and control uncertainty, supply and demand uncertainty. In this way, they have more accurate information allowing better forecasts and they will be able to react more efficiently to disruptions in the supply chain. In addition, best practices will be more widespread among different actors, which will further increase the efficiency as actors will improve their decision-making skills. The strategic relationships between supply chain actors, i.e. building linkages and sustaining a long-term partnership would increase the value transferred between entities in the supply chain and would decrease costs. Developing an integrated intermodal logistics system of Myanmar’s rice supply chain and trading network becomes increasingly more competitive in the regional and international rice markets.

Third, farmers should have a better knowledge of cultivation and post-harvesting techniques, climate risk mitigation strategies and new technologies via more efficient and widespread extension services. Accurate weather forecasts are crucial for farmers to organize their activities in a proactive manner. The Department of Agriculture and the Department of Meteorology should educate the farmers how to effectively use this information for their agricultural activities. Moreover, farmers should learn how to deal with adverse climate conditions. Best practices such as switching cultivating time, using early maturing and flood resistant rice varieties, improved land management e.g. erosion control and soil protection, etc. should be widespread practices among the farmers in the region. In order to establish a secure transportation system, the government should design and provide standard roads, rail and other infrastructure.

3.A Appendix

Table 3.A.1 Sampled respondents along the rice suppy chain in the study area

Actors	Townships	Total Population	Sampled respondents
Farmers	Myanaung (Laharpauk village)	399	30
	Myanaung (Htanthonepin village)	327	30
	Kyangin (Kyantaw village)	663	35
	Kyangin (Sonehele village)	630	35
Collectors	Myanaung	105	15
	Kyangin	60	6
Millers	Myanaung	132	18
	Kyangin	80	7
Wholesalers	Myanaung	34	4
	Kyangin	20	3
Retailers	Myanaung	103	20
	Kyangin	61	8
Rice Exporters	Yangon	36	4
	Total respondents		**215**

Source: DOA (2017) and MRF (2017)

Table 3.A.2 Characteristics of the different actors in the rice supply chain

Items	Unit	Para-meters	Farmer	Primary collector	Miller	Wholesaler	Retailer	Exporter
Gender	Number	Male	114 (87.69)	19 (90.48)	23 (92)	5 (71.43)	19 (67.86)	4 (100)
		Female	16 (12.31)	2 (9.52)	2 (8)	2 (28.57)	9 (32.14)	0 (0)
Age	Years	Mean	51	41.60	50.10	46.70	49.90	43
		Min.	27	25	30	41	30	35
		Max.	85	60	66	62	72	50
Family size	Numbers	Mean	4	4	4.40	4	3.60	4
		Min.	2	1	2	2	2	3
		Max.	8	7	8	6	6	6
Education	Schooling years	Mean	6	9	11	12.3	9.9	15
		Min.	2	5	5	6	4	15
		Max.	15	15	15	15	18	15
Work experience	Years	Mean	27	10.80	12.80	13	13.60	13
		Min.	3	1	1	3	1	5
		Max.	54	30	33	24	50	26
Farm size	ha	Mean	3.07	-	-	-	-	-
		Min.	0.40	-	-	-	-	-
		Max.	15.78	-	-	-	-	-
Small farm size	≤ 2.02 ha	Numbers	45 (34.62)	-	-	-	-	-
Medium farm size	> 2.02 ha and ≤ 4.05 ha	Numbers	49 (37.69)	-	-	-	-	-
Large farm size	> 4.05 ha	Numbers	36 (27.69)	-	-	-	-	-
Yield of Paddy	kg/ha	Mean	3000.11	-	-	-	-	-
		Min.	516.44	-	-	-	-	-
		Max.	5164.39	-	-	-	-	-
Milling amount	‘000kg/day	Mean	-	-	11.99	-	-	-
		Min.	-	-	0.21	-	-	-
		Max.	-	-	59.71	-	-	-
Milling capacity	< 15000 kg/day	Numbers	-	-	19 (76)	-	-	-
	≥ 15000 kg/day	Numbers	-	-	6 (24)	-	-	-
Marketed amount	'000kg/year	Mean	6.50	127.29	1088.17	669.74	25.73	507500
		Min.	0.29	10.45	12.68	13.46	13.80	60000
		Max.	31.04	627.00	3793.48	1776.75	189.75	1700000

Note: Figures in the parentheses represent percentage.
Source: Own survey (2017)

Table 3.A.3 Mean comparisons of the supply uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
SU1: Rice quantity from rice producers is unpredictable	Farmers	130	111.60	13.406^{**}	0.020
	Primary collectors	21	70.21		
	Millers	25	113.62		
	Wholesalers	7	123.07		
	Retailers	28	117.80		
	Exporters	4	59.13		
	Total	215			
SU2: Rice quality from rice producers is unpredictable	Farmers	130	108.77	5.691^{ns}	0.337
	Primary collectors	21	88.52		
	Millers	25	118.98		
	Wholesalers	7	103.36		
	Retailers	28	116.27		
	Exporters	4	66.88		
	Total	215			
SU3: Rice producers' delivery time is unpredictable	Farmers	130	106.47	10.916^{*}	0.053
	Primary collectors	21	95.19		
	Millers	25	118.34		
	Wholesalers	7	134.50		
	Retailers	28	119.59		
	Exporters	4	33.00		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ** = Significant at 5% level, * = Significant at 10%level and ns = Non-significant.

Source: Own survey (2017) and SPSS

Table 3.A.4 Mean comparisons of the demand uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
DU1: The volume of customer demand is difficult to predict	Farmers	130	101.35	11.32^{**}	0.045
	Primary collectors	21	98.98		
	Millers	25	127.96		
	Wholesalers	7	157.00		
	Retailers	28	119.04		
	Exporters	4	83.88		
	Total	215			
DU2: Customers' rice preference changes over the year	Farmers	130	102.40	8.444^{ns}	0.133
	Primary collectors	21	93.79		
	Millers	25	126.00		
	Wholesalers	7	141.86		
	Retailers	28	121.05		
	Exporters	4	101.38		
	Total	215			
DU3: The lead time of customer order is unpredictable	Farmers	130	108.13	2.800^{ns}	0.731
	Primary collectors	21	95.38		
	Millers	25	106.84		
	Wholesalers	7	125.64		
	Retailers	28	116.73		
	Exporters	4	85.25		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ** = Significant at 5% level, * = Significant at 10%level and ns = Non-significant.

Source: Own survey (2017) and SPSS

Table 3.A.5. Mean comparisons of the Processing uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
PU1: Yield of processing (e.g., milling, packing) can vary	Farmers	130	111.74	2.317 ns	0.804
	Primary collectors	21	96.07		
	Millers	25	103.94		
	Wholesalers	7	110.07		
	Retailers	28	106.45		
	Exporters	4	81.63		
	Total	215			
PU2: The quality of rice after processing (e.g., milled, stored) can change	Farmers	130	113.46	7.155 ns	0.209
	Primary collectors	21	86.45		
	Millers	25	117.84		
	Wholesalers	7	107.29		
	Retailers	28	93.73		
	Exporters	4	83.38		
	Total	215			
PU3: The throughput time of rice processing can vary	Farmers	130	101.18	8.709 ns	0.121
	Primary collectors	21	126.64		
	Millers	25	130.42		
	Wholesalers	7	128.93		
	Retailers	28	103.04		
	Exporters	4	89.75		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ns = Non-significant.

Source: Own survey (2017) and SPSS

Table 3.A.6. Mean comparisons of the planning and control uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
PCU1: Information about stock level of rice and rice production capacity is inaccurate	Farmers	130	102.89	7.366^{ns}	0.195
	Primary collectors	21	101.26		
	Millers	25	112.90		
	Wholesalers	7	100.64		
	Retailers	28	135.95		
	Exporters	4	96.00		
	Total	215			
PCU2: Information about stock level of rice and rice production capacity is not timely	Farmers	130	102.17	4.771^{ns}	0.444
	Primary collectors	21	127.19		
	Millers	25	108.00		
	Wholesalers	7	104.00		
	Retailers	28	122.13		
	Exporters	4	105.00		
	Total	215			
PCU3: Information concerning changes of customer orders cannot be distributed on time	Farmers	130	102.19	5.925^{ns}	0.314
	Primary collectors	21	132.38		
	Millers	25	104.94		
	Wholesalers	7	105.21		
	Retailers	28	121.11		
	Exporters	4	101.13		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ns = Non-significant.

Source: Own survey (2017) and SPSS

Table 3.A.7. Mean comparisons of the competitors' uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
CU1: Competitors' actions are unpredictable	Farmers	130	97.45	11.828^{**}	0.037
	Primary collectors	21	127.55		
	Millers	25	126.56		
	Wholesalers	7	144.93		
	Retailers	28	114.59		
	Exporters	4	121.63		
	Total	215			
CU2: Competition in the domestic market is intensifying	Farmers	130	99.91	8.423^{ns}	0.134
	Primary collectors	21	128.19		
	Millers	25	121.38		
	Wholesalers	7	142.71		
	Retailers	28	107.54		
	Exporters	4	123.88		
	Total	215			
CU3: Competition is intensified in different countries	Farmers	130	99.31	9.772^{ns}	0.082
	Primary collectors	21	137.12		
	Millers	25	123.70		
	Wholesalers	7	120.00		
	Retailers	28	107.25		
	Exporters	4	123.75		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ** = Significant at 5% level, * = Significant at 10%level and ns = Non-significant.

Source: Own survey (2017) and SPSS

Table 3.A.8. Mean comparisons of the government uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
GU1: Government policies in rice trading (e.g., FTA, tax) directly affecting your firms are unpredictable	Farmers	130	103.16	5.046[ns]	0.410
	Primary collectors	21	109.95		
	Millers	25	107.14		
	Wholesalers	7	128.86		
	Retailers	28	127.20		
	Exporters	4	89.63		
	Total	215			
GU2: The grantee price from government regulation is unpredictable	Farmers	130	102.92	12.241**	0.032
	Primary collectors	21	85.36		
	Millers	25	125.46		
	Wholesalers	7	156.21		
	Retailers	28	117.41		
	Exporters	4	132.75		
	Total	215			
GU3: New government regulation is introduced unexpectedly	Farmers	130	99.48	13.522***	0.019
	Primary collectors	21	113.24		
	Millers	25	121.82		
	Wholesalers	7	146.29		
	Retailers	28	129.66		
	Exporters	4	52.50		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. *** = Significant at 1% level, ** = Significant at 5% level and ns = Non-significant.
Source: Own survey (2017) and SPSS

Table 3.A.9. Mean comparisons of the climate uncertainty among the rice supply chain actors

Items	Group of actors	N	Mean Rank	Chi-Square value	Sig.
CLU1: Drought occurrences affecting firms are unpredictable in each year	Farmers	130	106.16	8.906^{ns}	0.113
	Primary collectors	21	114.79		
	Millers	25	116.48		
	Wholesalers	7	161.29		
	Retailers	28	92.29		
	Exporters	4	95.88		
	Total	215			
CLU2: The duration of drought is unpredictable over the years	Farmers	130	104.31	8.641^{ns}	0.124
	Primary collectors	21	115.29		
	Millers	25	120.32		
	Wholesalers	7	160.71		
	Retailers	28	96.98		
	Exporters	4	97.63		
	Total	215			
CLU3: Flooding occurrences affecting firms are unpredictable in each year	Farmers	130	105.09	7.599^{ns}	0.18
	Primary collectors	21	112.50		
	Millers	25	121.62		
	Wholesalers	7	153.71		
	Retailers	28	95.46		
	Exporters	4	101.50		
	Total	215			
CLU4: The duration of flooding is unpredictable over the years	Farmers	130	104.84	7.319^{ns}	0.198
	Primary collectors	21	113.90		
	Millers	25	120.98		
	Wholesalers	7	152.71		
	Retailers	28	98.11		
	Exporters	4	89.50		
	Total	215			

Note: Non–parametric statistics (Kruskal-Wallis) was used. ns = Non-significant.

Source: Own survey (2017) and SPSS

4

Measuring the Efficiency of the Rice Production in Myanmar using Data Envelopment Analysis: A Non-Parametric Approach

Rice production in Myanmar is constrained by bio-physical and socio-economic factors. Efficient farm practices can enhance productivity, farmers' profit and marketed rice. We present this study to analyze the profitability of the rice production, investigate the efficiency of the rice production and to identify socio-economic characteristics and farm-specific characteristics that influence this efficiency of the rice production in the Ayeyarwaddy Region, Myanmar. To that purpose, we collected primary data from 130 respondents in the Ayeyarwaddy Region by using a random sampling method and analyzed this data via descriptive statistics, Data Envelopment Analysis (DEA) and a Tobit regression analysis. According to the average overall technical efficiency, farmers have an additional rice yield potential of 25% that can be attained by improving the input utilization. The best practices of more efficient rice farms learn that the technical inefficiency is caused by the abundant use of inputs, especially of herbicides and animal power. Most of the rice farms in this study suffer from allocative and economic inefficiencies resulting from wrong combinations of input usages. The average economic efficiency level indicates that farmers can increase their profitability by 57% by adapting their input costs. The Tobit regression indicates that the efficiency is significantly higher for younger farmers, farmers that are better educated, have more experience and/or have knowledge of agricultural extension services and grow the Aye Yar Min variety. The efficiency in the rice production can be further improved by setting up cooperatives between different farmers to increase the scale of operations. Moreover, the government should intervene to reduce the input prices, control the quality of the input seeds and install an appropriate financial crop insurance mechanism. An effective agricultural extension services should be widespread in a systematic manner to improve the efficiency and decision-making skills of the rice farmers in the study area.

4.1 Introduction

Agriculture plays a major role in Myanmar's society by ensuring food security at community and national levels as well as in the provision of employment and income for a growing population. Agriculture is essential to the domestic economy of Myanmar. According to the Ministry of Agriculture and Irrigation (MOAI, 2015a), agricultural activities resulted in 22.1% of the Gross Domestic Product in 2014-2015. More than half of the population is directly employed in this sector. Rice plays an essential role not only in food security but also in the nation's economic development. In 2016-2017, rice production was reported being more than 19 million MT and the country exports were 1.5 million MT (USDA, 2017), worth about 439 million USD in 2016 (WTO, 2018). The country's average rice yield amounted about 3.84 MT/ha while the yield of Southeast Asia countries like in Vietnam was about 5.58 MT/ha in 2016 (FAO, 2017). In 2016, the paddy production in Myanmar was ranked 7th among the paddy producing countries in the world (World Rice Production, 2017). However, the yield and production of rice cultivation in Myanmar remains low compared to neighbouring countries whereas there is still a high potential for productivity increases (Zorya, 2016). According to Saysay (2016), rice production and supply is sensitive to profitability and improving profitability provides incentives to increase production and marketable surplus. The best and most effective way to improve productivity can be realized via a more efficient utilization of scare resources.

The variation in the rice yield reflects the current uneven distribution of agricultural inputs and skills. Different farmers have different resource availabilities, different input and output prices, and different optimal operating points (Ali & Flinn, 1989; Wang et al., 1996). Aung (2012) indicates the major factors that may increase the rice productivity are the types of rice varieties, fertilizers, agricultural chemicals, irrigation techniques and the policies of rural institutions supporting the agricultural sector. Improving the productivity of the rice industry could contribute to a poverty reduction leading to hunger eradication, national food security and economic development (FAO, 2004).

According to Amos (2007), efficiently utilizing the limited resources by the smallholder farmers in developing countries is a prerequisite to increase the food security and the farm income. In this study, we first analyze the profitability of the rice production using the enterprise budget. Second, we measure the technical, scale, allocative and economic efficiency of the rice production via Data Envelopment Analysis (DEA) to assess the potential for increasing the rice production in the Ayeyarwaddy Region, Myanmar. Lastly, we identify the socio-economic and farm-specific characteristics that influence the efficiency of the rice production in the Ayeyarwaddy Region, Myanmar. Our contribution is threefold. This is the first study to analyze technical, scale, allocative and economic efficiency of rice production in Myanmar using the DEA approach. This study can identify the most efficient farmers whose practices can be applied as a benchmark for others in the study area to improve the efficient utilization of scarce resources. Results of this study provide relevant recommendations for the farmers to better control the resource usage and improve the operational decision-making in the rice production especially for rural development and food security in Myanmar.

The remainder of the paper is organized as follows. Section 4.2 reviews the relevant literature on the production and economic efficiency of rice production. We describe the data collection, sampling procedure and methodology to examine the production and economic efficiency in Section 4.3. Section 4.4 presents the empirical results and Section 4.5 discusses the findings for the study. The conclusion and policy recommendations are summarized in Section 4.6.

4.2 Literature Review

4.2.1 Benchmarking efficiency using Data Envelopment Analysis

Efficiency can be understood in terms of a firm’s ability to convert inputs to outputs and respond optimally to economic signals or prices in production economics. When measuring the efficiency, we need to know the benchmarking between companies which operate in the same industry. The most popular techniques used to measure farm efficiency are Data Envelopment Analysis (DEA) using mathematical programming methods and the Stochastic Frontier Analysis (SFA) applying econometric methods (Sivarajah, 2017). DEA is a non-parametric, deterministic procedure for evaluating the frontier and employs the best-practice frontier (Bates et al., 1996). SFA is a parametric approach that requires the assumption of a specific function a priori even though it can estimate parameters for the function that incorporates error components: statistical noise associated with data measurement errors and a non-negative component that measures the inefficiency in production (Coelli et al., 2005). Therefore, DEA approach is less sensitive to misspecification relative to SFA (Watkins et al., 2014). In this study, we will focus on DEA approach to measure the different types of efficiency in rice production.

Data Envelopment Analysis (DEA), originally developed by Charnes, Cooper and Rhodes (1978) is a very powerful service management and benchmarking technique to evaluate nonprofit and public sector organizations. Linear programming (LP) is the methodology that makes DEA particularly powerful compared with other productivity management tools. DEA has been widely studied, used and analyzed by academics to evaluate the firm (the decision-making unit) performance using efficiency measurements. In the literature, distinction is made between the input-oriented and the output-oriented DEA model to measure the efficiency. The input-oriented DEA model minimizes the inputs keeping the outputs at their current level. The output-oriented DEA model maximizes the outputs are maximized keeping the inputs are fixed at their current level (Banker et al., 1984).

Different studies investigated the farm efficiencies of the rice production in developed and developing countries. Watkins (2014) and Nguyen et al. (2012) estimated the technical, scale, allocative and economic efficiency of rice production using panel data and an input-oriented DEA in the United States and South Korea, respectively. The empirical studies that measured the efficiency of rice production in developing countries are summarized in Table 4.1. All these studies applied cross-sectional data. In total, 13 studies published between 1999 and 2017 are listed in the table. For each of these studies, we listed the country, the type of efficiency measured, and the DEA model used (input-oriented vs output-oriented). All studies investigated the technical efficiency. Based on the types of analysis, nine studies use an input-oriented DEA; two studies apply an output-oriented DEA and two studies employ both an input-oriented and output-oriented DEA depending on their objectives in rice production and their input and output variables. Aung (2012) investigated the economic efficiency of rice production in Bago and Yangon regions in Myanmar by applying the technique Stochastic Frontier Analysis (SFA), used to analyze parametric data. The average economic efficiency of rice production is estimated at 0.84 for both regions.

Table 4.1 Empirical studies on efficiency measurement of rice production using DEA approach in developing countries

No.	Authors	Country	Efficiency	Type of analysis
1.	Linh et al. (2017)	Vietnam	Technical efficiency Scale efficiency	Input-Oriented
2.	Sivasankari et al. (2017)	India	Technical efficiency Scale efficiency	Input-Oriented
3.	Khan, Baten and Ramli (2016)	Malaysia	Technical efficiency Scale efficiency	Input-Oriented
4.	Ogunniyi et al. (2015)	Nigeria	Technical efficiency	Input-Oriented
5.	Mailena et al. (2014)	Malaysia	Technical efficiency Scale efficiency	Output-Oriented
6.	Tipi et al. (2010)	Turkey	Technical efficiency Scale efficiency	Input-Oriented
7.	Kiatpathomchai (2008)	Thailand	Technical efficiency Allocative efficiency Economic efficiency	Input-Oriented
8.	Brázdik (2006)	Indonesia	Technical efficiency	Input-Oriented
9.	Chauhan, Mohapatra, and Pandey (2006)	India	Technical efficiency	Input-Oriented
10.	Dhungana, Nuthall, and Nartea (2004)	Nepal	Technical efficiency Allocative efficiency Economic efficiency	Input-Oriented Output-Oriented
11.	Krasachat (2004)	Thailand	Technical efficiency	Input-Oriented
12.	Coelli, Rahman, and Thirtle (2002)	Bangladesh	Technical efficiency Allocative efficiency Economic efficiency	Input-Oriented
13.	Wadud (1999)	Bangladesh	Technical efficiency Allocative efficiency Economic efficiency	Input-Oriented Output-Oriented

Source: Own compilation based on literature

4.2.2 Impact of socio-economic and farm-specific characteristics on efficiency

The estimation of efficiency without clearly identifying important socio-economic and demographic, institutional and policy variables, has limited importance for policy and management purposes (Saysay, 2016). According to Rahman (2013), the determinants of farm production efficiency are categorized into three aspects based on the nature of relationship that exist between a farm and some factors within or outside the farm. These three aspects are the farm-farmer relationship (i.e. the influence of the farmer's socio-economic characteristics on farm production), the farm-institution relationship (i.e. the influence of agricultural extension, credit, research, infrastructure, etc.) and the farm-production relationship (i.e. the factor-product relationship to determine the most profitable mix of resources to produce a given output level or to determine the most profitable amount of output to produce at a given level of input). Most of the studies in the literature focus on the farmer-farm relationship. Linh et al. (2017), Ogunniyi et al. (2015), Mailena et al. (2014) and Dhungana (2004) indicated that education of the farmers impacted on the technical efficiency of the rice production. Moreover, Dhungana (2004) investigated that the education had a positive impact on the economic, allocative and scale efficiency. Linh et al. (2017), Ogunniyi et al. (2015), Tipi et al. (2010) and Kiatpathomchi (2008) found that total farm size and age of the farmers influenced the technical efficiency of the rice production. According to the study of Dhungana (2004), the age of the farmers had a negative impact on the technical, scale and economic efficiency of the rice production. Wadud (1999) observed that family size had a negative impact on the technical and economic efficiency. Ogunniyi et al. (2015) investigated that farming experience had a positive impact on the technical efficiency. However, Kiatpathomchi (2008) and Wadud (1999) indicated that the farming experience has a negative impact on the economic efficiency of the rice production. According to Kiatpathomchi (2008), the rice variety as an element of the farm-production relationship impacts negatively the technical efficiency and economic efficiency. Aung (2012) identified some relevant factors impacting the efficiency score for other regions in Myanmar, i.e. farmers cultivating a secondary crop attain a lower economic efficiency and farmers with a higher educational level accomplish a higher economic efficiency.

4.3 Materials and Methods

4.3.1 Data collection and sampling technique

Both primary and secondary data are collected for the rice production in two townships, Myanaung Township and Kyangyin Township in the Ayeyarwaddy Region, which is the largest rice production area in Myanmar (cf. Appendix 4.A.1). The random sampling method is used to collect primary data and the sample size is calculated from the direct proportion[9] compared to the (finite) population (cf. Appendix 4.A.2). A sample of 130 farmers is selected and in-depth interviews and key informant interviews have been conducted to interview sample respondents (Umberger, 2014). We collected socio-demographic data (age, education level, actor's experience in rice production and marketing, family size), production data (such as material inputs, family labor and hired labor, animal power, machine power, and their prices and wages) and financial data (such as credit sources and interest rates) and other related primary data. The secondary data was collected from the Department of Agriculture (DOA), Ministry of Agriculture, Livestock and Irrigation (MOALI), FAOSTAT, websites and other relevant data sources.

4.3.2 Research method: Benefit-Cost Analysis

The concept of enterprise budget (Olson, 2009) is used to evaluate the profitability of the rice production by the farmers. This enables us to evaluate the cost and return of the value adding activities. In order to estimate the return above variable cost or gross margin, the average yield and average price are used. To calculate the variable costs we take material costs, hired labor costs, family labor costs and the interest on cash costs into account by means of the mathematical expression (4.1).

Return above variable cost (RAVC) = Total Gross Benefit – Total Variable Cost *(4.1)*

[9] This is based on the equation of Yamane (1967), i.e. $n = \frac{N}{1+N(e^2)}$ where N is the population, e^2 is the standard error and n is the sample size.

4.3.3 Research method: Data Envelopment Analysis (DEA)

Data Envelopment Analysis enables to distinguish different kinds of efficiency such as technical, scale, allocative and economic efficiency, which are explained below.

4.3.3.1 Technical efficiency (TE) and scale efficiency (SE)

Technical efficiency is defined as the ability of a farm to either produce the maximum feasible output from a given bundle of inputs or to produce the given level of output using the minimum amount of inputs (Basanta et al., 2004). The technical efficiency can be measured under the assumption of *constant returns-to-scale* (CRS), which hypothesizes that the output will change in the same proportion as the inputs are changed. If the technical efficiency is measured under the assumption of *variable returns-to-scale* (VRS), the production technology is assumed to exhibit increasing and/or decreasing returns-to-scale (Kumar and Gulti, 2008). The technical efficiency with constant returns-to-scale (TE_{CRS}), which is further referred to as the *overall technical efficiency*, helps to determine inefficiencies due to input/output arrangement as well as the size of operations and is composed out of two components, i.e. the *pure technical efficiency* and the *scale efficiency* (Sharma et al., 1999). The *pure technical efficiency*, also called the technical efficiency with variable returns-to-scale (TE_{VRS}), is achieved by estimating the efficient frontier under the assumption of variable returns-to-scale. The pure technical efficiency makes abstraction of the scale effect and reveals the ability of the business unit to organize its inputs efficiently in the production process. Hence, the pure technical efficiency can be used as an index to capture the managerial performance of a decision maker. The ratio of the overall technical efficiency vs the pure technical efficiency provides the *scale efficiency* (SE). When the overall technical efficiency is equal to the pure technical efficiency, the business unit is called a scale-efficient unit. *Scale efficiency* expresses whether a firm is operating at its optimal size. The scale efficiency gives notion of the managerial ability to select the optimal resource input size and scale of production to achieve the expected production level (Kumar and Gulti, 2008). Scale inefficiency is the result from decreasing returns-to-scale (DRS) or increasing returns-to-scale (IRS). Decreasing returns-to-scale implies that a firm is too large to take full advantage of its scale and has a supra-optimum scale size. In contrast, a firm that is experiencing increasing returns-to-scale, is too small for its scale of operations and, thus, operates at sub-optimum scale size. A firm is scale efficient if it operates at constant returns-to-scale (CRS).

The TE score for a given farm n is obtained by solving the following input-oriented DEA model:

Notation

Sets

I	set of farms (index i)
J	set of inputs (index j)
K	set of outputs (index k)

Parameters

x_{ij}	the amount of input j used on farm i
x_{nj}	the amount of input j used on farm n
y_{ik}	the amount of output k produced on farm i
y_{nk}	the amount of output k produced on farm n

Decision variables

λ_i	the nonnegative weights for farm i
θ_n	the technical efficiency of farm n

Mathematical formulation

$$TE_n = \min \theta_n \qquad (4.2)$$

Subject to

$$\sum_{i=1}^{I} \lambda_i \, x_{ij} - \theta_n x_{nj} \le 0 \qquad \forall_j \qquad (4.3)$$

$$\sum_{i=1}^{I} \lambda_i \, y_{ik} - y_{nk} \ge 0 \qquad \forall_k \qquad (4.4)$$

$$\sum_{i=1}^{I} \lambda_i = 1 \qquad (4.5)$$

$$\lambda_i \ge 0 \qquad (4.6)$$

The objective function (eq. 4.2) of the input-oriented DEA model minimizes the inputs while the outputs are kept at their current levels. If θ_n is equal to 1, the business unit is technically efficient. When θ_n is smaller than 1, the business unit is technically inefficient with the inefficiency level equal to $1 - TE_n$ (Coelli, 1995). Equation (4.3) is the input constraint formulated for every input j. This constraint stipulates that the input used by farm n, weighted by its efficiency level θ_n, must exceed or be equal to a weighted combination of inputs used by the other farms. Equation (4.4) is the output constraint formulated for every output k. This constraint stipulates that the output obtained by farm n must be lower than or equal to the weighted combination of outputs obtained by the other farms. Equation (4.5) sets the sum of all weights given to the other farms equal to 1 and ensures that the technical efficiency TE_n is calculated under the assumption of variable returns-to-scale (VRS) (Coelli, 1995). Model (4.2)-(4.6) is the formulation proposed by Banker, Charnes, and Cooper (1984) and calculates the pure technical efficiency ($TE_n = TE_{VRS_n}$). When equation (4.5) is omitted, constant returns-to-scale (CRS) are assumed and the model reflects the formulation proposed by Charnes, Cooper, and Rhodes (1978) to calculate the overall technical efficiency ($TE_n = TE_{CRS_n}$).

The scale efficiency of farm n (SE_n) can be calculated by the following equation:

$$SE_n = \frac{TE_{CRS_n}}{TE_{VRS_n}} \tag{4.7}$$

4.3.2.2 Economic efficiency (EE)

Economic Efficiency (EE) is also known as cost efficiency and is calculated as the ratio of the minimum feasible costs and the actually observed costs for a decision-making unit (DMU) (Farrell, 1957). If a decision-making unit is both technically and allocative efficient, it is said to be economically efficient. The EE score for a given farm n is obtained via solving the following LP model to find the minimum cost:

Notation

Sets

I	set of farms (index i)
J	set of inputs (index j)
K	set of outputs (index k)

Parameters

x_{ij}	the amount of input j used on farm *i*
y_{ik}	the amount of output *k* produced on farm *i*
y_{nk}	the amount of output *k* produced on farm *n*
P_{nj}	the price for input *j* on farm *n*

Decision variables

λ_i	the nonnegative weights for farms *i*
x^*_{nj}	the cost-minimizing level of input *j* on farm *n* given its input price and output levels

EE input-oriented DEA model

$$MC_n = min_{\lambda_i x^*{}_{nj}} \sum_{j=1}^{J} P_{nj}\, x^*{}_{nj} \tag{4.8}$$

Subject to

$$\sum_{i=1}^{J} \lambda_i\, x_{ij} - x^*{}_{nj} \leq 0 \qquad \forall_i \tag{4.9}$$

$$\sum_{i=1}^{I} \lambda_i\, y_{ik} - y_{nk} \ \geq 0 \qquad \forall_k \tag{4.10}$$

$$\sum_{i=1}^{I} \lambda_i = 1 \tag{4.11}$$

$$\lambda_i \ \geq 0 \tag{4.12}$$

The objective function (eq. 4.8) of the input-oriented model to measure the economic efficiency minimizes the costs of rice production while the outputs are kept at their current levels. Equation (4.9) is the input constraint for every input *j*. This constraint stipulates that the inputs of farm *n* must exceed or be equal to the weighted combination of inputs used by the other farms. Equation (4.10) is the output constraint formulated for every output k. The output obtained by farm n must be lower than or equal to the weighted combination of outputs obtained by the other farms. Equation (4.11) sets the sum of all weights given to the other farms equal to 1 and ensures the minimum cost in equation (4.8) is calculated under the assumption of variable returns-to-scale (VRS) (Fletschner and Zepeda, 2002; Wu and Prato, 2006). The economic efficiency of farm n (EE_n) can then be calculated based on equation (4.13), i.e.

$$EE_n = \frac{\sum_{j=1}^{J} P_{nj}\, x^*{}_{nj}}{\sum_{j=1}^{J} P_{nj}\, x_{nj}} \tag{4.13}$$

where, the numerator is the minimum total cost obtained for farm n based on model (4.8)-(4.12) and the denominator is the actual total cost observed for farm n. $EE_n = 1$ indicates that the farm is economically efficient and $EE_n < 1$ indicates that the farm is economically inefficient.

4.3.2.3 Allocative efficiency (AE)

Allocative efficiency or price efficiency is defined as the ability of a farm to use the inputs in optimal proportions, given their respective prices and the production technology (Farrell, 1957). In other words, allocative efficiency is the ability to select a combination of inputs to produce a set of outputs at minimum cost. Allocative efficiency can be calculated by the following equation:

$$AE_n = \frac{EE_n}{TE_n} \tag{4.14}$$

where

EE_n	the economic efficiency calculated for farm n using eq. (4.13)
TE_n	the technical efficiency calculated for farm n using model (4.2)-(4.6).

If $AE_n = 1$ the farm is price efficient and $AE_n < 1$ means that the farm is price inefficient.

4.3.3 Research method: Tobit regression model

The Tobit regression model is used to perform a regression analysis to determine the significant socio-economic and farm-specific characteristics that hinder the rice production efficiency, which is obtained via DEA. Tobit analysis assumes that the dependent variable has a number of factors clustered at a limiting value, usually zero (Tobin, 1958). Hence, the following regression model is employed.

$$y_i^* = x_i\beta_i + \mu_i \quad i = 1, 2, \dots, n \tag{4.15}$$

$$y_i = y_i^* \; if \;\; y_i^* < 0 \tag{4.16}$$

$$y_i = 0, otherwise \tag{4.17}$$

where

$\mu_i \sim N(0, \sigma^2)$	the error terms
x_i	explanatory variables
β_i	estimated parameter coefficients
y_i^*	a latent variable
y_i	the efficiency scores obtained via the DEA model

4.4 Empirical Results

4.4.1 Rice production and profitability of the farmers in the study area

The rice cultivation steps conducted in the study area are detailed in Table 4.2. Table 4.3 gives an adequate idea of the input uses of rice production and presents the profitability of the rice production in the study area by calculating the enterprise budget (cf. Table 4.3). In the study area, rice is cultivated in two seasons: monsoon and summer. This study investigates the Emata varieties grown in the monsoon rice production period which only relies on rainfall. For the monsoon rice, the fields are tilled around the beginning of June. Land preparation such as ploughing and harrowing together with the application of farm yard manure (2 ton/ha) and compound fertilizer (42.39 kg/ha) is mainly done by animal power and human labour. Some farmers use tractors for land preparation. Before land preparation, seed beds are prepared by sowing rice seeds (104.48 kg/ha) in nurseries in the last week of May. The rice seedlings are transplanted between 15 and 21 days to the rice fields. After planting, rice crops are cared for by using herbicides (3.44 kg/ha or 0.21 L/ha), using fertilizers (104.92 kg/ha of urea, 4.87 kg/ha of potash and 9.51 kg/ha of T-super), controlling the weed manually, using pesticides (0.04 kg/ha or 0.35 L/ha) and irrigating water, which are all done by human labour. Urea fertilizer and pesticides are normally applied three times before harvesting. Harvesting and threshing is done by human labour in the late of October and at the beginning of November. Combined harvesting machines are rarely used to harvest and thresh the rice in the study area. After threshing, the rice is dried by human labour and the transportation is mainly performed by animal power. The total labour used for all rice production activities is on average 5.82 animal-day/ha for animal power, 7.18 machine-day/ha for machine power and 68.12 man-day/ha for for both family and hired human labour.

The results of Table 4.3 give insights in the production system and the costs and profits of the farmers from the monsoon rice production for Emata rice varieties. The farmers in the study area obtain the average paddy yield of 3000.11 kg/ha by using the average amount of inputs shown in the table. The average total gross benefits 708026 MMK/ha and the average total variable cost is 629166 MMK/ha. Hence, the return above variable cost (RAVC) amounts 78860 MMK/ha. Based upon the return on investment, farmers receive a profit 13 MMK in return for an investment of 100 MMK in Emata rice. The total variable costs are covered if the sample farmers receive a price of 210 MMK/kg. The rice farmers achieve very few amounts of profit from the rice production, which just cover their cost of production. Therefore, the rice farmers are not profitable on average in rice production in the study area.

Table 4.2 Rice cultivation steps (transplanting method) practicing by the farmers in the study area

Month	Week	Activities
May	1	
	2	
	3	Seedbed preparation for nursery, herbicide application
	4	Seed broadcasting on the seedbeds
June	1	Land preparation for the field, application of FYM and Compound fertilizers
	2	
	3	Uprooting the seedlings and transplanting them to the field
	4	
July	1	Herbicide application, pesticide application
	2	
	3	
	4	Application of urea fertilizer and Potash, irrigation
August	1	Drainage
	2	
	3	Application of urea fertilizer and T-super, and herbicide application
	4	Manual weeding
September	1	Pesticide application and urea fertilizer application
	2	Pesticide application, irrigation
	3	
	4	Drainage
October	1	
	2	
	3	
	4	Harvesting, threshing, transporting and drying
November	1	
	2	
	3	
	4	

Note: These cultivation steps are in general. Farmers manage their rice cultivation depending on the different conditions.

Source: Own survey (2017)

Table 4.3 Enterprise budget and benefit cost analysis of the monsoon rice production in 2016 for the Emata rice by the farmers (N=130)

Items	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of paddy	kg/ha	3000.11	236	
Total gross benefit	**MMK/ha**			**708026**
2. Variable Cost				
(a) Material Cost				
Seed	kg/ha	104.48	336	35105
FYM	ton/ha	2.00	7487	14974
Urea fertilizer	kg/ha	104.92	481	50467
Potash	kg/ha	4.87	950	4627
T-super	kg/ha	9.51	960	9130
Compound fertilizer	kg/ha	42.39	520	22043
Pesticides (Powder)	kg/ha	0.04	25461	1018
Pesticides (Liquid)	L/ha	0.35	17500	6125
Herbicide (powder)	kg/ha	3.44	7919	27241
Herbicide (Liquid)	L/ha	0.21	17172	3606
Fuel	gal/ha	1.51	2943	4444
Total Material Cost(a)	**MMK/ha**			**178780**
(b) Family Labor Cost				
Land preparation (machine)	Machine day /ha	2.24	9439	21143
Land Preparation	Amd/ha	4.18	4288	17924
Manure application	Md/ha	2.57	3157	8113
Picking	Md/ha	1.94	2228	4322
Seeding	Md/ha	2.34	2527	5913
Transplanting	Md/ha	0.51	3558	1815
Irrigation& drainage	Md/ha	2.47	3083	7615
Manual Weeding	Md/ha	0.65	2186	1421
Fertilizer application	Md/ha	4.43	2544	11270
Pesticides application	Md/ha	1.06	2641	2799
Herbicide application	Md/ha	1.96	2587	5071
Harvesting	Md/ha	0.27	3946	1065

Table 4.3 Enterprise budget and benefit cost analysis of the monsoon rice production in 2016 for the Emata rice by the farmers (Continued)

Items	Unit	Level	Effective Price	Total Value
Drying	Md/ha	0.74	3206	2372
Total family labor cost(b)	**MMK/ha**			**90844**
(c) Hired Labor Cost				
Land preparation (machine)	Machine day /ha	3.94	9439	37190
Land Preparation	Amd/ha	1.64	4288	7032
Picking	Md/ha	3.80	2280	8664
Seeding	Md/ha	1.22	2527	3083
Transplanting	Md/ha	21.31	3558	75821
Manual Weeding	Md/ha	7.62	2186	16657
Fertilizer application	Md/ha	0.46	2544	1170
Pesticides application	Md/ha	0.21	2641	555
Herbicide application	Md/ha	0.23	2587	595
Harvesting	Md/ha	14.33	3946	56546
Harvesting and threshing by combine harvester	MMK/ha	0.42	42850	17997
Threshing by machine	Machine day/ha	0.58	20573	11932
Transportation	MMK/ha			7500
Drying	Md/ha	0.11	3206	353
Total Hired Labor Cost	**MMK/ha**			**245096**
(d) Interest on cash cost				
Material cost	MMK/ha	178780	0.27	48270
Hired labor cost	MMK/ha	245096	0.27	66176
Interest on cash cost	**MMK/ha**			**114446**
Total variable costs (a + b + c + d)				629166
Return above variable costs				78860
Return per unit of capital invested (B/C ratio)				1.13
Break-even price (MMK/kg)				210
Break-even yield (Kg/ha)				2665.96

Note: kg = kilogram, ha = hectare, MMK = currency of Myanmar (Myanmar kyats), L = litre, gal = gallon, Md = man-days, Amd = Animal-days,

Source: Own survey (2017)

4.4.1 Technical, allocative and economic efficiency of the rice farmers

4.4.1.1 Descriptive statistics of input and output

In this section, we use the types of inputs which are applied by the majority of the farmers in the rice production to measure the farm efficiency. The summary of statistics of the input and output variables to analyse the technical, allocative and economic efficiency are reported in Table 4.4. The output is measured as kilograms of rice yield. The average rice yield of the sampled farms is 3000.11 kg/ha with a minimum yield of 516.44 kg and a maximum yield of 5164.39 kg. The standard deviation of the paddy yield is quite high, which indicates the large variability among the sampled farms. The inputs are the amount of seeds, amount of urea fertilizer, amount of herbicides, animal labour, machine and human labour and their corresponding price information. Among the inputs, the mean total man labour used is 68.12 man-days/ha with a standard deviation of 25.33 man-days/ha, which labels the rice production in the study area as labour intensive (Ogunniyi et al., 2015). The data in this table is used as input for calculating the input-oriented technical efficiency using the model (4.2)-(4.6), the economic efficiency using model (4.8)-(4.13) and the allocative efficiency using equation (4.14). The results are shown in Table 4.5.

Table 4.4 Descriptive statistics of the input, output and prices of the variable inputs of the sampled farms (N=130)

Variables		Unit	Mean	Minimum	Maximum	Std. Deviation
Output variables	Rice yield	kg/ha	3000.11	516.44	5164.39	818.49
Input variables	Seed rate	kg/ha	104.48	77.47	180.75	17.27
	Urea fertilizer	kg/ha	104.92	0.00	247.10	52.47
	Herbicide	kg/ha	3.44	0.00	7.41	4.62
	Animal power	animal-day/ha	5.82	0.00	22.24	6.13
	Machine power	machine-day/ha	7.18	1.00	15.83	4.04
	Human labour	man-day/ha	68.12	7.41	155.67	25.33
	Price of seed	MMK/kg	336.26	143.54	542.25	85.82
	Price of urea fertilizer	MMK/kg	480.80	340.00	960.00	73.31
	Price of herbicide	MMK/kg	7919.23	3000.00	40000.00	7709.81
	Wage of animal power	MMK/animal-day	4288.46	3500.00	5000.00	603.17
	Price for machine power	MMK/machine-day	20575.00	2000.00	65000.00	13286.51
	Wage of human labour	MMK/man-day	2856.91	2000.00	3428.57	283.99

Note: we assumed 1 USD = 1350 MMK

Source: Own survey (2017)

4.4.1.2 Technical efficiency and scale efficiency

Technical efficiency

According to the results of Table 4.5, the average overall technical efficiency score (TE_{CRS}) is 0.75. Hence, as this factor is smaller than 1, most of the farmers in the study area do not utilize their production resources in the most efficient manner. Farmers do not obtain the maximal output from the given level of inputs. As a result, the sample farmers can increase the technical efficiency by 25% via the adoption of the best farm practices of the efficient farms, i.e. farmers with an efficiency score θ_n equal to 1. The result is consistent with the findings of different countries: Sri Lanka (0.75) (Thibbotuwawa et al., 2012); South Korea (0.77) (Nguyen et al., 2012); India (0.76) (Sivasankari et al., 2017); India (0.77) (Chauhan et al., 2006) and Nepal (0.76) (Dhungana et al., 2004). The average pure technical efficiency score (TE_{VRS}) is 0.90, which indicates that about 10% of the inefficiency can be addressed by improving the managerial skills of the farmers such that they are able to use their inputs more efficiently. The result is very close to the findings of Chauhan et al., (2006) conducted in India.

Scale efficiency

The scale efficiency provides useful information for the farmers to know whether or not their scale of production should be changed in order to improve efficiency. The average scale efficiency score is 0.83 (= TE_{CRS}/TE_{VRS} = 0.75/0.90). Hence, the technical efficiency can be improved by 17% by adapting the scale of the farms. The average scale efficiency score obtained in our study is similar to the findings of Ogunniyi et al. (2015), Khan et al. (2016) and Chauhan et al. (2006). However, different from the result in our study, Sivasankari et al. (2017), Linh et al. (2017), Ogunniyi et al. (2015), Khan et al. (2016), Tipi et al. (2010), Dhungna et al. (2004), Krasachat (2004), Coelli et al. (2002) and Wadud (1999) observed that the scale efficiency is larger than the pure technical efficiency (TE_{VRS}). A further analysis of the scale efficiency reveals that 43.85% of the farmers achieve more than 0.90 showing these farms are operating quite close to the optimal rate given their scale. The observed returns-to-scale of the sampled rice farms are presented in Table 4.5. Out of 130 farms, about 20.77% of them operate at constant returns-to-scale. About 73.08% of the farms show increasing returns-to-scale indicating that most of the farms in the sample are too small and, therefore, these rice farms would benefit from an increase in their scale in rice production. Only 6.15% of the farms operate at decreasing returns-to-scale (i.e. operating above their optimal scale). Hence, the majority of the farms in the study area have a substantial scale inefficiency and they should be larger than their present operating size in order to achieve a more efficient and higher production. The scale of operations can be increased via setting up cooperatives in rice production and exploiting the economics of scale.

Input slacks and excess input use

The optimum solution of the DEA model provides input and output slacks corresponding to the input and output constraints. Slacks exist only for inefficient DMUs and indicate how these inefficient farms can improve their operations and their technical efficiency (Jacobs et al., 2006). From the concept of an input-oriented DEA efficiency analysis, the technical efficiency can be improved by the proportional reduction of one or multiple inputs while still attaining the same output (Kiatpathomchai, 2008). Table 4.6 gives insight in the input slacks given the VRS assumption. Since slack indicates the excess of an input, a farm can reduce its expenditure on the input by the amount of slack without reducing its output (Sivsankari, 2017). Almost all the inputs are used excessively. The mean slacks for the seed rate and the urea fertilizer are 2.61 kg/ha and 8.26 kg/ha, respectively. These excess amounts of seed and fertilizer are wasted in the production process. The percentage of herbicide slack is the highest (35.17%) among all inputs used in the rice production. Moreover, the mean slack for animal power, machine power and human labour are 0.98 animal-day/ha, 0.48 machine-day/ha and 2.45 man-day/ha, respectively. The largest input excess of labor used in the rice production is animal labour (16.84%). This data reveals that the rice production in the study area is still very traditional and improvements can be realized via farm mechanization.

4.4.1.3 Allocative efficiency and economic efficiency

Allocative efficiency

An analysis of the allocative efficiency reveals that most rice farmers employ an inefficient input mix, given the input prices (cf. Table 4.5). As a result, their costs are on average 43% higher compared to the most efficient farm and they can reduce their costs by carefully considering the relative input prices when selecting input quantities. The mean allocative efficiency in the study area is very low compared to other countries (United States (Watkins, 2014), Malaysia (Khan et al., 2016), Sri Lanka (Thibbotuwawa et al., 2012), Thailand (Kiatpathomchai, 2008), Nepal (Dhungana et al., 2004) and Bangladesh (Coelli et al., 2002 and Wadud, 1999)) ranging between 0.71 and 0.91 for rice production. We may conclude that farmers in Myanmar need better guidance and information to select the appropriate combination of inputs given the input prices.

Economic efficiency

According to the results of Table 4.5, only one farm (0.77%) is economically efficient and about 24.60% of the farms have an acceptable economic efficiency ranging between 0.51 and 0.90. The majority of the farms (74.63%) are not economically efficient and have a score lower than 0.51. These results confirm that the rice farmers are economically inefficient and the total cost of rice production for each farm could be reduced by 57% on average to achieve the same level of output. The economic efficiency is very low in the study area compared to other countries (such as United States, Sri Lanka, Thailand, Nepal and Bangladesh), for which the mean economic efficiency ranges between 0.52 and 0.78 for rice production.

Excess input use in the economic efficiency

Table 4.7 indicates the distribution of the excess inputs given the economic efficiency. We also have displayed the optimal input combination that minimizes the input costs. Since the percentage of excess use (prices of inputs are taken into account in the cost minimization) in machine power (61.92%) and human labour (78.12%) is very high compared to other inputs, the rice farmers should carefully manage their excess use of labour.

4.4.1.4 Description of the best practices for rice production

According to the results in Table 4.5, only one farmer among the sampled rice farmers is technically, allocative and economically efficient. The remaining 129 farmers are not economically efficient in their rice production. Table 4.8 represents the percentage of the farmers who achieve the same output level or have the same input level compared to this efficient farmer. The purpose of this description is to set a best practice and to allow other farmers to learn how they can improve their efficiency. The efficient farmer yields 3098.63 kg/ha of paddy. In total, 21 other farmers (16.28%) have the same or a higher production level. Most of the other farmers use the best practice level of seeds (75.19%) and urea fertilizer (69.77%). However, the benchmark learns that only a few other farmers are as efficient with respect to the other resources, i.e. herbicide (1.55%), animal power (6.98%), machine power (7.83%) and human labour (0.78%). Table 8 further reveals the input prices paid by the most efficient farmer for seed, urea fertilizer, herbicide, animal power, machine power and human labour. The other farmers pay the best practice prices for the herbicides (37.98%), animal power (36.43%), urea fertilizer (20.16%) and seed rate (15.50%) compared to the most efficient farmer. However, all farmers do not receive the best prices for the machine and human labour compared to the farmer of most efficient farm.

Table 4.5 Frequency distribution of rice farms on the technical, allocative and economic efficiency index

Efficiency Level	Technical Efficiency						Allocative Efficiency		Economic Efficiency	
	TE_{CRS} (Overall TE)		TE_{VRS} (Pure TE)		Scale Efficiency (SE)		(AE)		(EE)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
0.01 – 0.10	0	0.00	0	0.00	0	0.00	0	0.00	1	0.77
0.11 – 0.20	4	3.08	0	0.00	3	2.31	0	0.00	6	4.62
0.21 – 0.30	1	0.77	0	0.00	1	0.77	1	0.77	15	11.54
0.31 – 0.40	3	2.31	0	0.00	3	2.31	7	5.38	43	33.08
0.41 – 0.50	5	3.85	0	0.00	3	2.31	26	20.00	32	24.62
0.51 – 0.60	15	11.54	1	0.77	6	4.62	50	38.46	19	14.62
0.61 – 0.70	24	18.46	3	2.31	8	6.15	36	27.69	11	8.46
0.71 – 0.80	24	18.46	30	23.08	23	17.69	8	6.15	2	1.54
0.81 – 0.90	16	12.31	23	17.69	26	20.00	1	0.77	0	0.00
0.91 – 1.00	38	29.23	73	56.15	57	43.85	1	0.77	1	0.77
Mean	0.75		0.90		0.83		0.57		0.43	
Minimum	0.15		0.59		0.15		0.28		0.07	
Maximum	1.00		1.00		1.00		1.00		1.00	
IRS	-		-		73.08%		-		-	
DRS	-		-		6.15%		-		-	
CRS	-		-		20.77%		-		-	

Source: Own survey (2017) and DEAP 2.1

Table 4.6 Distribution of input slacks for achieving the optimum paddy yield

Inputs	Unit	Mean slack	Mean input used	Excess input used out of mean input used (%)	Number of farmers
Seed rate	kg/ha	2.61	104.48	2.50	16
Urea fertilizer	kg/ha	8.26	104.92	7.87	29
Herbicide	kg/ha	1.21	3.44	35.17	47
Animal power	animal-day/ha	0.98	5.82	16.84	38
Machine power	machine-day/ha	0.48	7.18	6.69	29
Human labor	man-day/ha	2.45	68.12	3.60	23

Source: Own survey (2017) and DEAP 2.1

Table 4.7 Distribution of excess input used for achieving minimum costs of rice production

Inputs	Unit	Mean cost minimizing input used	Mean input used	Excess input used	Excess input used out of mean input used (%)
Seed rate	kg/ha	86.04	104.48	18.44	17.65
Urea fertilizer	kg/ha	103.85	104.92	1.07	1.02
Herbicide	kg/ha	3.01	3.44	0.43	12.50
Animal power	animal-day/ha	4.52	5.82	1.30	22.41
Machine power	machine-day/ha	2.73	7.18	4.45	61.92
Human labor	man-day/ha	14.90	68.12	53.22	78.12

Source: Own survey (2017) and DEAP 2.1

Table 4.8 Distribution of farmers following the best practice farmer in achieving optimal output and using optimal input level

Output and Inputs	Unit	Best Practice level	Frequency of farmers who followed the best practice level (N=129)	Percentage of farmers who followed the best practice level (N=129)
Rice yield	kg/ha	3098.63	21	16.28
Inputs				
Seed rate	kg/ha	103.29	97	75.19
Urea fertilizer	kg/ha	123.55	90	69.77
Herbicide	kg/ha	0.37	2	1.55
Animal power	animal-day/ha	9.88	9	6.98
Machine power	machine-day/ha	1.00	23	17.83
Human labor	man-day/ha	22.24	1	0.78
Prices				
Seed rate	MMK/kg	334.93	20	15.50
Urea fertilizer	MMK/kg	460.00	26	20.16
Herbicide	MMK/kg	6000.00	49	37.98
Animal power	MMK/animal-day	5000.00	47	36.43
Machine power	MMK/machine-day	50000.00	0	0.00
Human labor	MMK/man-day	2300.00	0	0.00

Note: we assumed 1 USD = 1350 MMK

Source: Own survey (2017) and DEAP 2.1

4.4.2 Farm specific factors related to farm efficiency

In this section, we attempt to examine factors affecting the efficiency by following a two-step approach as suggested by Coelli and Basttese (1996). To determine the influencing factors, the Tobit model is applied via Eviews 9 to regress the efficiency scores on the farm characteristics. The dependent variables are the efficiency scores calculated in Section 4.4.1. Table 4.9 describes the summary statistics of the independent farm-specific variables. These independent variables are age, family size, education, experience (farm-farmer variables); farm size and rice variety (farm-production variables) and received extension services (farm-institution variable). Among these variables, the rice variety used is an important input for achieving a high yield (Ataboh et al., 2014). The varieties used by the farmers in the study area are Aye Yar Min, Sin Thu Kha, Shwe War Tun, Yadanar-toe, Kayin Ma, Shwe Wa Ti and Pale Thwe. In our analysis, we group the farmers in two groups, i.e. the farmers who grow the Aye Yar Min variety and the farmers who do not. Farmers that grow the Aye Yar Min variety obtain a higher profit since they receive a higher price for this variety of high quality and the Aye Yar Min variety is also a high yielding variety (Linn and Maenhout, 2018a). Another independent variable is the agricultural extension services received by the farmers (Taraka et al., 2011), which implies a knowledge information transfer from extension agents to farmers such that farmers can make better decisions based on their own objectives and possibilities. This independent variable is a binary variable, i.e. farmers participate in the extension program or do not.

Table 4.10 indicates the results of the Tobit regression analysis for the technical efficiency, the scale efficiency, the allocative efficiency and the economic efficiency of the rice farmers. All independent variables except family size and farm size are significant factors impacting the efficiency of a farm in one way or another. In our discussion, we only indicate the significant relationships.

The age of the farmers negatively impacts the technical efficiency under the assumption of constant returns-to-scale, which confirms the findings of Ogunniyi et al. (2015) and Tipi et al. (2010). The age of the farmers has also a negative and significant impact on the scale efficiency, allocative efficiency and economic efficiency. This implies that younger farmers are more efficient than older farmers. In-depth interviews revealed that younger farmers accept new technologies in rice production more easily. Older farmers are more likely in need to have contacts with extension agents and are less willing to adopt new practices and modern inputs.

Education is an important factor indicating the ability of farmers to receive and understand information regarding modern technologies. The more educated farmers perform better in terms of the technical, scale and economic efficiency as a result of their access to information and good farm planning (Linn and Maenhout, 2018b). This result confirms the studies of Linh et al. (2017), Mailena et al. (2014) and Dhungana et al. (2004) but is not consistent with the finding of Ogunniyi et al. (2015).

Experience in rice farming has a positive impact on the allocative efficiency and the economic efficiency, which indicates that the experienced farmers are more efficient in the usage of their input resources. Experience improves the decision-making of farmers. This study contradicts the findings of Kiatpathomchai (2008) and Wadud (1999).

The farmers that grow the Aye Yar Min variety are more efficient compared to the farmers that do not. However, the type of variety used is not related to the allocative efficiency, i.e. the allocation of inputs by the farmers in rice production at given prices of inputs. This result is consistent with the findings of Watkins (2014) and Kiatpathomchai (2008).

According to Backman et al. (2011), extension services guide the farmers to access the well-farm management methods and to the more effective use of scarce resources. The extension services received by the farmers have a positive and significant impact on all types of efficiency except for the allocative efficiency. This means that even though the extension services are received by rice farmers, the allocation of resources is not impacted because price information is included in the allocative efficiency. Farmers who receive or participate to the services provided by the agricultural extension agents are more efficient as a result of the technical assistance to the farmers, information sharing, and the training courses supported by the Department of Agriculture and other private agricultural pesticides companies. This study confirms the results of Jaforullah and Whiteman (1999).

Table 4.9 Descriptive statistics of socio-economic variables for the sample farms (N=130)

Variables	Unit	Mean	Minimum	Maximum
Age	Year	51.09	27.0	85.00
Family size	Number	4.00	2.00	8.00
Education	Schooling year	6.58	2.00	15.00
Experience	Year	27.07	3.00	54.00
Farm size	ha	3.07	0.40	15.78
Variety used		1 = Aye Yar Min, 0 = others		
Received extension services		1 = Yes, 0 = No		

Source: Own survey (2017)

Table 4.10 Results of Tobit regression coefficients (N=130)

Independent Variables	TE_{CRS}	TE_{VRS}	SE	AE	EE
Constant	0.6225*** (0.0917)	0.8825*** (0.0531)	0.6987*** (0.0855)	0.5599*** (0.0514)	0.3361*** (0.0606)
Age	-0.0041** (0.0017)	-0.0009 (0.0009)	-0.0035** (0.0015)	-0.0021** (0.0009)	-0.0038*** (0.0011)
Family size	-0.0028 (0.0131)	-0.0035 (0.0076)	-0.0006 (0.0122)	0.0089 (0.0073)	0.0021 (0.0087)
Education	0.0174*** (0.0065)	0.0014 (0.0014)	0.0189*** (0.0061)	0.0056 (0.0008)	0.0162*** (0.0043)
Experience	0.0023 (0.0016)	0.0003 (0.0009)	0.0019 (0.0015)	0.0019** (0.0038)	0.0027*** (0.0011)
Farm size	-0.0000 (0.0069)	-0.0028 (0.0227)	0.0017 (0.0064)	-0.0055 (0.0220)	-0.0039 (0.0045)
Variety used	0.1479*** (0.0392)	0.0598*** (0.0185)	0.1115*** (0.0366)	0.0135 (0.0179)	0.0978*** (0.0259)
Received extension services	0.1135*** (0.0319)	0.0418** (0.0185)	0.0885*** (0.0298)	0.0033 (0.0514)	0.0697*** (0.0211)
SE of regression	0.1852	0.1072	0.1726	0.1038	0.1224
Wald Chi-Square	47.3736***	13.7616*	41.4958***	12.4492*	61.2085***
Log likelihood	39.4354	110.4767	48.5859	114.6713	93.2603
Likelihood ratio (LR) test	40.3928***	13.0804***	36.0119***	11.8880*	50.1563***

Dependent variables are TE_{CRS} index, TE_{VRS} index, SE index, AE index and EE index.

Note: Figures in the parentheses are standard error.

* = significant at 10% level, ** = significant at 5% level and *** = significant at 1% level.

Source: Own survey (2017) and Eviews 9.

4.5 Discussion

The *profitability* of the rice production by the farmers is very low. Rice farmers get lower output prices especially during the harvesting period, but they pay higher prices for their inputs used in the rice production. The benefit-cost ratio of rice production, i.e. 1.13, in our study is lower than the result (1.61) of Kiatpathomchai (2008) in Thailand. The average yield in Thailand is higher than that of Myanmar. In addition, according to Kiatpathomchai (2008), farmers from Thailand do not use animal power in any activities and use mostly machine power and human labour in rice production. The profitability of the rice farmers is highly related to the efficiency. If they can manage their inputs effectively and efficiently, they can earn more profit from rice production. Kiatpathomchai (2008), Dhungana et al. (2004), Coelli et al. (2002) and Wadud (1999) also analysed technical, allocative and economic efficiency of rice production. The information and results of their studies are presented in Table 4.11. In our study, we have included many more inputs in the analysis. In particular, the herbicide input has not been considered before as an input variable in all other studies. The pure technical efficiency of our study is higher than the results found by Dhungana et al. (2004), Coelli et al. (2002) and Wadud (1999) but, is slightly lower than the result of Kiatpathomchai (2008). These benchmarking studies have been proven to be useful by getting insight in the input resource mix decision of the efficient farms and to find the weakness of the current cultivation techniques (Dhungana et al., 2004).

Technical inefficiency in our study results largely from the abundant use of herbicides and animal power. We can infer from overuse of herbicides that the weeds problem in the rice fields in the study area is serious and can cause low rice yield. Therefore, they used a lot of herbicide unsystematically and carelessly, which makes negative effect to yield. The inefficient mix of input resources utilized results from the perceived uncertainty by the decision maker on the one hand (Linn and Maenhout, 2018b) and the operational constraints imposed on the other hand (Linn and Maenhout, 2018a). In Linn and Maenhout (2018b), the climate uncertainty was revealed as the major source of environmental uncertainty impacting the rice supply chain. When making decisions under large uncertainty, it is much more difficult to the select the accurate and most efficient mix of resources. In response, an appropriate financial insurance mechanism should be implemented by the government or private partners to buffer the financial implications of unexpected crop failure for farmers. According to Linn and Maenhout (2018a), crop cultivation in Myanmar is still carried out according to traditional farming activities and most farmers lack the appropriate level of mechanization to increase the efficiency as they do not have the knowledge nor financial resources to invest. Therefore, the government should develop a farm mechanization and cultivation program in cooperation with private institutions and provide the appropriate (public) infrastructure, the knowledge transfer to learn farmers how to adapt their farm and farming techniques and the acquisition of farm machinery by farmers via low interest loans.

On average the rice farms in the study area are *scale inefficient*. The result of scale efficiency of our study is lower than those of other studies of Dhungana et al. (2004), Coelli et al. (2002) and Wadud (1999) (cf. Table 4.10) as a result of the (too) small scale of many farms operating in Myanmar. In order to achieve economies of scales, organization of small scale cultivations should be promoted to be comparatively larger collective systems consisting of multiple farmers with the collaboration of the government, farmer organizations and the private sector (Thibbothwawa et al., 2012). Establishing cooperatives between farmers will increase the scale of operations.

Allocative and economic inefficiency of rice production can be attributed largely to the abundant use of labour and input seeds in our study. The economic inefficiency of rice production in Thailand resulted from the overuse of fertilizers (Kiatpathomchai, 2008); in Bangladesh from the abundant use of labour (both animal power and human labor) and fertilizer (Coelli et al., 2002); and in Sri Lanka from the inefficient use of human labor, machinery and seed (Thibbotuwawa et al., 2012). Associated with the *high demand for labour*, the labour unit price is high. The agricultural activities in Myanmar are very labour intensive as they are still carried out in a traditional manner and are not mechanized properly. Farm mechanization plays an important role in improving the quality of paddy and reducing postharvest losses, but the acquisition of the required machinery is too expensive for farmers in Myanmar. The scarcity of labour during transplanting, weeding, and harvest time results in losses, both in the quantity and quality of the rice output. Raising farm efficiency, lowering unit costs, and reducing postharvest losses will increase rice production and thus the profits of farmers. To solve the labour scarcity problem, government and private partners should provide a farm mechanization extension program to transfer the required technological knowledge to the farmers and affordable loans with low interest rates.

The *input seeds* and the used *variety* is an important factor impacting the efficiency of the rice farms. The use of good-quality and pure seed is of high importance to maximize the paddy quality and the resulting profit. However, the famers are thwarted as the seeds used by most of the farmers are impure because they produce the seeds on their own farms using traditional methods (Wong and Wai, 2013; Linn and Maenhout, 2018a). In addition, the uncertainty related to the production inputs impacts the managerial decision-making and the related farming efficiency (Linn and Maenhout, 2018b). Good quality and pure seed availability is a necessary condition for a higher yield and better quality of rice production and should be controlled by the government. The functioning of the (state) seed production companies should be revised such that all farmers have access to high-quality seeds at the least possible cost. The decision-making managerial skills can be further improved by public or private investments in the schooling system and the extension system to transfer knowledge between farmers and researchers. A better *education* of the actors enhances the decision-making and communication skills with any support service providers such as extension officers and other stakeholders in the business. In line with the research of Dhungana et al. (2004), government initiatives in collaboration with private partners should be installed to educate the inefficient farmers and learn the best farming practices applying extension tools such as field days on the efficient farms (Dhungana et al. (2004). The system of *extension services* needs to be reformed to increase the mobility of extension officers, improve links between farmers, researchers and extension staff and the use of modern technologies for agricultural extension. New skills are needed for the new era of global agricultural engagement. The efficient agricultural extension system has to be implemented by the Department of Agriculture, MOALI cooperated by the International Non-Government Organizations (INGOs), Non-Government Organizations (NGOs) and private agrochemical companies.

Table 4.11 Information of input and output variables and results of efficiency scores via DEA in rice production in some developing countries

Country	Authors	Mean efficiency results	Output variable	Input variables
Myanmar	This study (2018)	TE (VRS) = 0.90 AE (CRS) = 0.57 EE (CRS) = 0.43 SE = 0.83 CRS = 20.77% DRS = 6.15% IRS = 73.08%	Rice yield (kg/ha)	Seed rate (kg/ha) Urea fertilizer (kg/ha) Herbicide (kg/ha) Animal power (animal-day/ha) Machine power (machine-day/ha) Human labor (man-day/ha) Price of seed (MMK/kg) Price of urea fertilizer (MMK/kg) Price of herbicide (MMK/kg) Wage of animal power (MMK/animal-day)

				Price of machine power (MMK/machine-day) Wage of human labor (MMK/man-day)
Thailand	Kiatpathomchai (2008)	TE (VRS) = 0.92 AE (VRS) = 0.78 EE (VRS) = 0.68	Rice yield (kg/ha)	Labor (man-hr/ha) Machine (THB/ha) Seed (Kg/ha) Fertilizers: DAP (kg/ha) Urea (kg/ha) N-fertilizer (kg/ha) P-fertilizer (kg/ha)
Nepal	Dhungana et al. (2004)	TE (VRS) = 0.82 AE (CRS) = 0.87 EE (CRS) = 0.66 SE = 0.93 CRS = 10.52% DRS = 42.12% IRS = 47.36%	Rice yield (kg/farm)	Land (ha) Seed (kg/farm) Labor (Person days/farm) Mechanical labor costs (Rs./farm) Fertilizer costs (Rs./farm)
Bangladesh	Coelli et al. (2002)	TE (VRS) = 0.69 AE (VRS) = 0.81 EE (VRS) = 0.56 SE = 0.95 CRS = 10.90% DRS = 58.06% IRS = 31.04%	Rice output (kg)	Land cultivated (ha) Animal power (pair-days) Fertilizer (kg) Seed (kg) Labor (day) Land rent (taka/ha) Fertilizer price (taka/kg) Seed price (taka/ha) Labor wage (taka/ha) Animal wage (taka/pair)
Bangladesh	Wadud (1999)	TE (VRS) = 0.85 AE (VRS) = 0.87 EE (VRS) = 0.79 SE = 0.93 CRS = 16.67% DRS = 62.66% IRS = 20.67%	Output (Maund/ac) (1Maund = 37.32 kg)	Land (ac) Labor (man-day/ac) Irrigated land (ac) Fertilizer applied (kg/ac) Pesticides used (milliliter)

Source: Own compilation based on the literature

4.6 Conclusion and Recommendations

This study first investigates the profitability of the rice production in the Ayeyarwaddy Region, Myanmar. In order to evaluate the performance of the rice production, we estimate the technical, scale, allocative and economic efficiency scores by using an input-oriented DEA model. Tobit analysis is used to explore the factors influencing the efficiency scores of the rice farmers. The lack of empirical studies in Myanmar, which focus on the efficiency performance using DEA and the factors impacting this efficiency motivates this study.

The empirical results in this study reveal that there is a huge potential to increase the efficiency of rice farms in Myanmar. The farmers in the study area are not profitable from the rice production resulting from inefficiencies. The best practices of more efficient rice farms learn that the technical inefficiency is caused by the overconsumption of inputs, especially of herbicides and animal power. In addition, most of the rice farmers in this region produce rice at increasing returns-to-scale indicating that they should increase their scale of operations. Moreover, the allocative efficiency and the economic efficiency are very low due to an inappropriate management, i.e. the selection of wrong input combinations and high input costs. Especially the high costs for machine power and human labour are the cause for the economic inefficiency. A regression analysis gives us some insights in the determinants of the inefficient performance of the farmers. We found that some farm-farmer related variables, i.e., age, education and experience, impact the farm efficiency. The variety used (farm-production related variable) and the extension services received by the farmers (farm-institution related variable) also impact the technical, scale and economic efficiency of the rice farmers.

Our findings pose several important policy implications. The low economic efficiency reveals the potential to increase the output levels considerably, which will further enhance farm income and the welfare of the farm households. Government should intervene in the input and output prices for the farmers in order to improve the allocative and economic efficiency of rice production. Moreover, the agricultural mechanization should be introduced to further lower costs and should be realized via the cooperation of private and public organizations. The most efficient farms could be encouraged to disseminate their best practices and to share their experience with other farms to improve the average farm efficiency in the study area. A solution is to increase the scale of farming operations by setting up cooperatives between different farmers, similar to other ASEAN countries. In this

way, farmers have a stronger bargaining position leading to lower input and higher output prices, price fluctuations will be less volatile, more accurate market information can be gathered and a better market orientation is obtained. In addition, best practices and extension programs will be transferred to a higher number of farmers in a more efficient manner.
The education of farmers is an important determinant of the rice farm efficiency. In the long run, better performance in the agricultural sector can be achieved by increasing the private and public investments in education in rural areas initiating programs to encourage those at school-going age. However, in the short run, farmers may learn the agricultural technologies from the benchmarking practices of the relatively efficient farms. These practices can be spread via extension services or informally via setting up cooperatives between different parties. Moreover, the farmer field schools (FFS) program, supported by different development agencies cooperating with the Department of Agriculture, may be rigorously implemented to help farmers improve their analytical and decision-making skills in agricultural production.

Using quality seeds and growing the Aye Yar Min variety help to maximise efficiency. Hence, the transformation of state seed production should be done with extreme care in order not to deteriorate the seed quality. Good quality and pure seed availability is a necessary condition for a higher yield and better quality of rice production. The seeds used by most of the farmers are impure because they produce the seeds on their own farms using traditional methods. Growing the high-quality Aye Yar Min variety helps to increase the farmers' profit.

Extension programs have to be widespread among farmers to optimise the mix of farming inputs and production methods. The extension policy needs to be reformed to reorganize the duties of extension officials so that they can spend more time on field visits to the rice farmers. This would reduce the variation in actual output from the maximum potential output in the rice production.

4.A Appendix

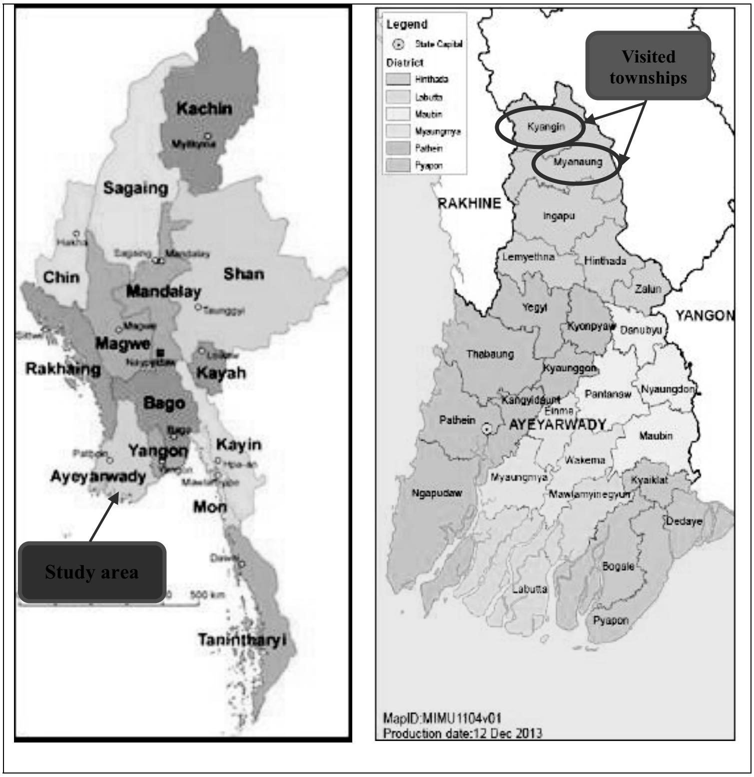

Figure 4.A.1 Map of Myanmar and Ayeyarwaddy Region which shows the studied townships

Source: DOA (2017)

Table 4.A.1 Sampled respondents for the rice production in the study area

Townships	Total Population	Sampled respondents
Myanaung (Laharpauk village)	399	30
Myanaung (Htanthonepin village)	327	30
Kyangin (Kyantaw village)	663	35
Kyangin (Sonehele village)	630	35
Total		**130**

Source: DOA (2017)

5

Conclusions and Future Research Avenues

5.1 Conclusions

We conclude this dissertation by summarising the major findings of the studies presented in chapters 2 to 4 by referring to the conclusion sections of the respective chapters. Future research ideas that related to these studies are also presented in the following section (Section 5.2).

Operational constraints in the rice value chain

The analysis of the operational constraints that hinder the development of the rice value chain in the Ayeyarwaddy Region has been investigated in Chapter 2. We have structured the rice value chain with different actors: farmers, primary collectors, millers, wholesalers, retailers and exporters. They have their own role in the value chain. After mapping these actors, firstly, we have calculated the cost and benefit of the rice farmers for their rice production. Based on this financial data, we analyse the marketing cost, margin and profit of the other actors in the value chain and of the global rice value chain. We have found that the value chain is inefficiently structured as it is characterized by many of actors who face several constraints. Moreover, the gross marketing margin across the global value chain is very wide and is not equally distributed over the different actors. Not all actors receive a reasonable profit margin. Among the value chain actors, the millers receive the highest percentage share of the profit and the primary collector and the farmers obtain the lowest marketing profit in both the domestic and international rice value chains. We have found that the socio-demographic characteristics and operational constraints faced by the different actors influence their profitability. Socio-demographic characteristics such as education level and work experience have a significant and positive impact on the profits of farmers, millers, wholesalers and retailers. The actors suffer especially from natural disasters and weather-related constraints, financial constraints and distributional and institutional constraints. All these constraints have a significant and negative impact on the profitability of the actors in the supply chain. In order to improve and upgrade the value chain operations, we provide several recommendations.

Uncertainty in the rice supply chain

Chapter 3 has confirmed that there are several uncertainty factors in the rice supply chain in the Ayeyarwaddy Region, Myanmar. In this chapter, we investigate how uncertainty affects the decision-making performance of the different types of actors in the rice value chain i.e.

farmers, rice millers, wholesalers, retailers and exporters. The important uncertainty factors are planning and control, climate and competitor uncertainty. The performance of the rice supply chain is poor according to a very low mean overall technical efficiency score because of notable scale inefficiencies. A majority of the business units need to expand their operating size. This chapter has also confirmed that uncertainty can harm the rice supply chain performance. Especially, planning and control and climate uncertainty adversely affect the supply chain efficiency. We investigated the impact of the uncertainty on the supply chain performance by grouping three stages: the production (farmers), processing (millers) and distribution (wholesalers, retailers and exporters). The actors suffer from the specific uncertainty sources depending on their role in the supply chain. Farmers face negative effects of climate and uncertainty in planning and control. The millers in particular suffer significantly from process uncertainty while the distributors face the adverse impact of demand uncertainty. Both the climate, and planning and control uncertainty present in the early production stages of the supply chain and have a negative and significant impact on different types of efficiency leading to the poor performance of the entire supply chain. Therefore, capturing and sharing information in the supply chain is crucial to the operational planning and control as the quality of information input directly impacts the quality of managerial decision-making. Moreover, public awareness of the impact of climate conditions on the agricultural production systems deserves priority consideration. Mitigating technologies must be developed to reduce the impact of the adverse climate conditions, which will require increased public and private investment.

Efficiency of rice production

Chapter 4 has measured the efficiency of the rice production by the farmers in the Ayeyarwaddy Region. The farmers in the study area are not profitable from rice production resulting from inefficiencies. Technical efficiency score resulted from input-oriented DEA model has confirmed that farmers have an additional rice yield potential of 25% that can be attained by improving the input utilization. The best practices of more efficient rice farms learn that the technical inefficiency is caused by the overconsumption of inputs, especially of herbicides and animal power. In addition, most of the rice farmers in this region produce rice at increasing returns-to-scale indicating that they should increase their scale of operations. Most of the rice farms in this study suffer from allocative and economic inefficiencies resulting from wrong combinations of input usages. Especially the high costs for machine power and human labour are the cause the economic inefficiency. The average economic efficiency level indicates that farmers can increase their profitability by 57% by adapting their input costs. We have identified some farm-farmer related variables i.e., age, education and experience, which impact the farm efficiency. The variety used (farm-production related variable) and the extension services received by the farmers (farm-institution related variable) also impact the technical, scale and economic efficiency. Government should intervene in the input and output prices for the farmers in order to improve the allocative and economic efficiency of rice production. Moreover, the agricultural mechanization should be introduced to further lower costs and should be realized via the cooperation of private and public organizations. The most efficient farms could be encouraged to disseminate their best practices and to share their experience with other farms to improve the average farm efficiency in the study area. A solution is to increase the scale of farming operations by setting up cooperatives between different farmers, similar to other ASEAN countries. In this way, farmers have a stronger bargaining position leading to lower input and higher output prices, price fluctuations will be less volatile, more accurate market information can be gathered and a better market orientation is obtained. In addition, best practices and extension programs will be transferred to a higher number of farmers in a more efficient manner.

General conclusion

We have investigated three different studies related to the operations of the rice industry i.e. a constraint analysis of the rice value chain, a study related to the uncertainty and performance of the supply chain and an efficiency analysis of the rice production step in the study area. We have found that the efficiency and performance of the rice value chain in Myanmar is very poor because of unequal distribution of profits and a very low technical and scale efficiency of the chain. The farmers are the most vulnerable actor in the rice value chain because their profit is lower, and they are economically inefficient in their rice production. We have observed that the actors along the rice value chain in Myanmar face several constraints and many types of uncertainty hindering their efficiency, performance and sustainability of the chain and causing the complexity to increase the efficiency of their business. The higher the degree of complexity they have, the lower the efficiency of the business they receive. This complexity depends on the number of constraints and types of uncertainty experienced by the actors. To increase the efficiency of their business, it depends on their managerial skills how to utilize and allocate their resources, minimize the constraints and mitigate the uncertainty, socio-economic and demographic factors, and institutional factors.

We could find some possible solutions to increase the efficiency and performance of the rice value chain which may improve the food security and reduce the rural poverty.

First, the stakeholders need to undertake different actions to improve the quality of rice. The availability of good-quality and pure seeds is essential to increase the yield and the quality of the rice production and to become a significant exporter in the global rice market. The government should revise the functioning of the (state) seed production companies to ensure that all farmers have access to high-quality seeds at the least possible cost. Moreover, the seed industry should develop the production of early maturing, drought resistant and flood resistant varieties of rice to cope with the vagaries of the climate. This measure reduces both the uncertainty related to the inputs and the weather and the constraints to produce high-quality paddy.

Second, the serious problems of natural disasters, unfavourable weather constraints and climate uncertainty for rice production that can adversely impact the performance and sustainability of the rice industry and food security have to be considered with the high priority. An agricultural or crop insurance mechanism should be installed at the farm level to mitigate the climate or natural disaster uncertainty. An appropriate financial insurance mechanism should be implemented by the government and private partners for all rice supply chain actors and in particular for the farmers.

Third, the successful co-ordination across farmers, processors, wholesalers, retailers, exporters and other stakeholders in the rice value chain is required to improve the rice value chain leading to cost reduction and farm-income enhancement for the farmers. The strengthening of the linkages between the rice value chain actors will also allow those actors to take better advantage of market opportunities and deserves high priority to develop the value chain and to improve the food security and reduce poverty. Linkages between upstream and downstream segments need to improve for facilitating the strengthening of comprehensive supply chains which compete with each other so as to contribute to increased competitiveness and increased productivity. In addition, the scale of the business for all actors are too small. The co-ordination and negotiation between actors in the same stage can increase the economies of scale of their business in the supply chain. The strategic relationships between supply chain actors, i.e. building linkages and sustaining a long-term partnership would increase the value transferred between entities in the supply chain and would decrease costs.

Fourth, education and work experiences of the stakeholders are crucial to increase the rice productivity, profitability and performance of the business for making right decisions on the input uses and effective management to cope with the constraints and uncertainty in operating business. In the long run, better performance in the agricultural sector can be achieved by increasing the private and public investments in education. In the short run, the performance of the companies can be improved by adopting the best practices of more efficient ones. In addition, most of the constraints and uncertainty can be mitigated if more and better agricultural extension services are offered to farmers. The extension system needs to be reformed, i.e. the mobility of extension officers should be increased, the links between farmers, researchers and extension staff should be improved and farmers should be encouraged to learn the latest technologies and new skills required for the new global agricultural era.

Fifth, the crop cultivation is further hindered by traditional farming activities, which may be solved via the promotion and realizing of farm mechanization for land preparation, cultivation and post-harvest activities. Moreover, many millers use outdated machines and electricity power shortage to process the rice leading to an inferior rice quality and reduce efficiency of the mills, respectively. Therefore, the government should develop a farm mechanization and cultivation program for the farmers in cooperation with private institutions and should support an affordable loan and investments to the millers to implement the improved milling machines and reliable electricity infrastructure with low costs.

Last, farmers, millers and distributors (wholesalers, retailers and exporters) need all low interest investment credits to modernize and expand their operations and infrastructure such that the production and rice quality can be increased. Increasing the rice productivity by using good quality seeds and modern production technologies, adopting mitigation strategies to uncertainty, developing mechanization, maintaining and upgrading road and electricity infrastructure, and expanding the financial services for all actors will improve the performance of the rice value chain in Myanmar leading to improve food security and reduce poverty.

5.2 Future Research

In this dissertation, we provide a number of studies that may be expanded and adapted in future research. Before describing the future research, firstly, we want to describe some limitations of this study.

- This study focuses only on the horizontal rice value chain in Myanmar due to limited time and budget. The research methodology and analysis in this study are based only on a questionnaire approach.
- When we conducted the survey to collect the primary data, we could not reach a sufficient number of wholesalers because of limited population size in the study area.
- This study only emphasizes the value chain for the Emata rice varieties. Therefore, this study could not analyse for each variety produced by the farmers, processed by millers and distributed by wholesalers, retailers and exporters because of limited data availability as a result of their poor data recording.
- The information on uncertainty studied in this dissertation is subjective information from the respondents. More accurate measurements to quantify the uncertainty in the supply chain are required.
- The efficiency inferences from cross-sectional data do not give any indication of year to year variability in production and efficiency.

Chapter 2 investigates only the rice value chain (horizontal chain) in the Ayeyarwaddy Region. We can expand our research by investigating the value chain of other value-added products (vertical chain) such as rice flour, rice noodles, rice vermicelli, rice snacks etc in order to have a better documented overview of the rice industry in Myanmar. In addition, we can compare the rice value chain in this study area to other regions in order to uncover a more nuanced view on the situation of the various actors and their constraints in those regions. Another important consideration of the rice sector is to promote Myanmar rice as a quality brand to enhance its competitiveness in international trade. Therefore, the rice value chain analysis and competitive advantage for the high quality special rice could also be investigated. Moreover, Chapter 2 could fill the gap related to the fifth objective of the rice sector (*reduction in the weaknesses along the rice value chain)*, by providing the interventions by the government and private partners cooperation with the civil society. However, further studies on how to minimize postharvest losses to increase the market value of rice production and improve rice food quality should be investigated. The supply chain management approach to postharvest losses is also important to study because the inefficiency and ineffectiveness of management in supply chains are the major reasons for the postharvest losses. Therefore, the research emphasized on value chains and postharvest operations needs further investigation in future studies because tremendous opportunities exist for improving food quality, diversity and safety as well as reducing post-harvest losses through enhancements of the rice value chain. This will realise the third objective of the rice sector emphasizing the improvement of rice food quality, safety, competitiveness and fairness in domestic and international markets. In addition, in this study, we just describe the major constraints faced by the actors in the rice value chain. We could not optimize the constraints because different stakeholders have their own multiple objective optimization problems and multiple constraints. The constraint problem is a very complex problem because each actor has their own constraints. If we study a constrained optimization problem, first we need to know the major constraints among many constraints. Then, we can continue in detail to get the data in quantitatively. Therefore, this constrained optimization problem can be studied in future research.

Chapter 3 emphasizes the uncertainty and supply chain performance of the rice sector in Myanmar. However, besides uncertainty, the risks faced by the different actors and the entire supply chain can be investigated in an objective manner. We can emphasize the risk identification including probability, severity and management or control, risk mitigation strategies (proactive and reactive strategies) and risk governance for the entire supply chain. Under the supply chain management, which is an important issue for all sectors, the rice supply chain practices and supply chain integration should be investigated in future research. Further, we measured only the supply chain performance in terms of efficiency. The study could be expanded to measure the supply chain performance in the view of flexibility, responsiveness and food quality. The ability to make good decisions can have great implications on business performance and, therefore, supply chain management is essential for effective planning in business processes. Forecasting plays a critical role in supply chain planning because important decisions are based on anticipated future variables such as marketed amount or product sales (Martine et al., 2003). Therefore, longitudinal data analysis will be used to forecast the strong performance of the business of the rice sector in future study. The impact of a longitudinal study is that we can establish sequences of events i.e. cause and effect for dynamic aspects of a problem. In this way, the results are smoothened over different years and outliers in the results will be filtered out. The results will be less sensitive to the moment data is captured. Observations on different moment in time will allow us to identify the impact of measures or policies set to reduce the uncertainty and constraints in the value chain.

Chapter 2 and 3 could fill the ninth challenge of the rice sector "*the unsatisfactory integrated value chain from rice production to trading and marketing*" by studying the operational constraints and uncertainty in the rice value chain. Moreover, this dissertation revealed that this challenge is also linked with other challenges such as adverse climate change effects, limited access to technological innovations, imperfect facilities for the postharvest handling and processes, insufficient infrastructure, product price volatility. However, it still needs a detailed study on these challenges. The *first and essential concern* is the effect of climate change on the rice value chain. Global climate change is an important challenge especially for the agriculture supported for food security. The increased frequency and intensity of extreme events such as drought and flooding, and the rise in temperature that are likely to result from global climate change will strongly affect rice production. A research focused on the climate change mitigation/adaptation and risk management on the rice production is crucial because climate changes seriously impact food security. The *second concern* is the product price volatility. Rice prices affect poverty, which was estimated at 37.5 percent in 2010 (World Bank, 2014). Rice price volatility is of concern to the Myanmar government, given the high importance of rice for farm incomes and consumer expenditures, and thereby for food security and poverty reduction (World Bank, 2014). A possible future direction would be to study the causes of rice price volatility and to identify the options for reducing rice price volatility to achieve food security objectives.

Chapter 4 investigates the efficiency of the rice production only for the rainfed rice. Therefore, we can study the efficiency of the summer rice production by the farmers. In rice production, the farmers face many types of production risk which plays a vital role in the decision making on input allocations and, therefore, output supply. Therefore, the impact of production risks on the efficiency of the rice production should be investigated as the future study. Moreover, climate change affects seriously the agricultural activities and directly impacts the rice production. The adaptation to this climate change reduces the negative impact (Adger et al., 2003) and will be imperative to meet the food security. Therefore, the impact of adaptation strategies to climate change on the productivity and efficiency of rice production which can consequently raise the returns of the farmers should be investigated in future research. In addition, we could study the overall technical, pure technical, scale, allocative and economic efficiency only for the rice production stage in Chapter 4. If the price information and amount of the inputs used for all activities in the business operated by all actors along the rice supply chain can be obtained exactly, we can measure the economic efficiency of the entire supply chain in Myanmar.

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