What Role does Agricultural Innovativeness Play in Explaining Technical Efficiency of the Agriculture Sector in Different Developing Countries?

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Contents

Abstract

Agriculture is important for economic activities in developing countries. This thesis uses a stochastic frontier analysis to investigate the level of agricultural technical efficiency for 14 developing countries in Asia during 2002 to 2010, focusing in particular on the impact of agricultural innovativeness. In addition, this thesis introduces the agricultural innovation system to describe the level of agricultural innovativeness in developing countries and explores how different components of the agricultural innovation system affect the technical efficiency in agriculture. Empirical results show that the average technical efficiency is 88.4 percent which indicates that there is still room to increase agricultural productivity. Countries like Bangladesh, China, India, Iran, Jordan, Pakistan and Vietnam have higher average efficiency scores. In terms of the role of the innovation system, results show that a larger scientific output, measured as the number of scientific journal articles, as well as foreign direct investments can increase agricultural technical efficiency. In contrast, countries that have better telephone and road networks, and that have more official development assistance are not performing well in agricultural technical efficiency.

Key words: agricultural innovativeness agricultural innovation system, technical efficiency, developing countries.

1. Introduction

Agriculture accounts for a significant share of economic activities and more than 60% of people are engaged in some form of agriculture in developing countries. Furthermore, the level of agricultural productivity greatly affects the development of other sectors in the economy. In developing countries, the agricultural sector is often characterized by low levels of productivity, small-scale of production, acute susceptibility to weather shocks and low levels of market integration and value addition(Mekonnen, Spielman et al. 2012). Today, more than ever, developing-country's agriculture needs to evolve to a more dynamic, responsive and competitive sector because of the rapid changes in the global market, especially the global food and agricultural market. These rapid changes are the result of major structural changes in the global agri-food system, including integration of the agri-food sector in global markets, the rise of the consumers as drivers of technological change, the growth of new private investment in agricultural technology and the revolution in information and communication technology(Bank 2007). Improving agricultural productivity in developing countries requires a better understanding of how innovation can contribute to developing countries' technical efficiencies(Mekonnen, Spielman et al. 2012).

Few studies exist within the vast literature on agricultural efficiency calculations that include innovation indicators in their analysis (Mekonnen, Spielman et al. 2012). This thesis tries to open the "black box" of agricultural innovativeness in developing countries and investigates the role that agricultural innovativeness plays in explaining differences in technical efficiency of the agricultural sector in developing countries. To achieve this objective, the thesis first discusses the agricultural innovation system as a key concept of innovativeness. Next, the thesis will present a framework and methodology for agricultural efficiency analysis. Finally, the thesis presents a quantitative study to estimate the impact of agricultural innovativeness on efficiency in a number of Asian developing countries.

Recent studies have moved from a linear model of innovation – in which innovation is seen as the result of the sequence of research, development and dissemination – to the concept of the ''agricultural innovation system (AIS)'' as the key determinant of a country's innovation success(Spielman and Birner 2008). The agricultural innovation system is "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way in which different agents interact, share, access, exchange and use knowledge" (World Bank 2006,vi-vii). Spielman and Kelemework (2009) explore a method to measure agricultural innovation system properties and performance and provide a toolkit for collecting and analyzing "system-oriented" indicators. Their toolkit will be used in this thesis as a basis for the analysis of agricultural innovation systems in developing countries(Spielman 2009).

There are two commonly used approaches in efficiency analysis: Data Envelopment Analysis (DEA, a non-parametric method) and Stochastic Frontier Analysis (SFA, a parametric method). DEA is based on the analysis of inputs and outputs to identify the efficiency of production and does not need a specified production function with related parameters. In contrast, SFA is based on an estimated production function and the separation of technical inefficiency and random effects leads to technical efficiency scores(Odeck 2007). One of the disadvantages of the DEA approach is that the DEA model does not consider random factors. SFA can overcome this problem. A large number of studies exists that use stochastic frontier analysis to estimate technical efficiency measures. However, few of them analyze the technical efficiency of the agricultural sector at the country level. Furthermore, few studies include agricultural innovativeness as a determinant of technical efficiency (see Mekonnen et al (2012) and Spielman and Birner (2008) for notable exceptions). This thesis uses panel data on inputs, outputs and the agricultural innovation system for 14 developing countries in Asia between 2002 and 2010 to estimate the technical efficiency of agriculture.

The main contributions of this research to the existing literature are: the estimation of the impact of innovativeness on agricultural productivity; the focus on the agricultural sector both in the efficiency calculations and the measurement of the innovation system indicators; and the focus on developing countries in Asia.

This thesis proceeds as follows. Chapter 2 will present the literature review about the basic conceptual framework of the agricultural innovation system. Chapter 3 discusses the econometric efficiency analysis methodology, specifically the estimation of the stochastic frontier production function. The hypotheses used to describe the innovation system in developing-country agriculture are also discussed in this chapter. This Chapter also presents the data, data sources, and the descriptive statistics for the data used in the analysis. The results of the econometric estimation are presented in Chapter 4. This chapter also includes the discussion of the impact of agricultural innovativeness on technical efficiency. Chapter 5 summarizes and concludes the thesis.

2. Agricultural Innovation System Framework

This chapter presents the literature review about the agricultural innovation system. The chapter will illustrate the system from three aspects: (1) introducing the evolution of the agricultural innovation systems approach; (2) sketching the conceptual framework of the agricultural innovation system; (3) assessing the key factors that explain the character and performance of agricultural innovation systems.

2.1. The Evolution of the agricultural innovation systems approach

In the past 40 years, a wide range of approaches emerged to agricultural innovation(Spielman and Birner 2008). There are three main conceptual frameworks: the national agricultural research system; the agricultural knowledge and information system; and the agricultural innovation system. Table 1 presents the overview of these three approaches.

The national agricultural research system (NARS) was developed during the 1970s as the product of neoclassical economics thinking and the focus on inherent market failures for agricultural research in developing countries (Alston, Chan-Kang et al. 2000, Spielman and Birner 2008) . The primary mission of NARS is to use public investment efficiently. Knowledge is the outcome of scientific research and innovation occurs through technology transfers. Apart from the stimulation of scientific research, public funds are employed to develop infrastructure and build human capacity to facility technology development and transfer.

The agricultural knowledge and information system (AKIS) provides a more systems-based approach to agricultural innovation. Röling (1990) defines AKIS as “a set of agricultural organizations and/or persons, and the links and interactions between them, engaged in such processes as the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilization of knowledge and information, with the purpose of working synergetically to support decision-making, problem solving and innovation in a given country’s agriculture or domain thereof (Roling 1990).” Unlike NARS, the desired outcome of AKIS is the adoption of technology through interactive learning. AKIS also pays attention to the knowledge network in the system in order to recognize the actors that can contribute to innovation system.

The agricultural innovation system (AIS) is promoted by researchers since the end of the 1990s. The World Bank (2006, vi-vii) gives a definition of the innovation system: “A network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance. The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways”(Pound and Essegbey 2008). The AIS approach not only emphasizes the importance of technology for innovation but also highlights the need for institutional change and the importance of the enabling environment of the system.

The three different approaches presented in Table 1 are not exclusive. AIS is a further development of NARS. There are also similarities between AIS and AKIS. Some researchers such as (Rivera, Alex et al. 2006) treat both approaches as parallel developments. This is also shown in the similarities of the definitions of both concept (Assefa, Waters-Bayer et al. 2009).

Table 1: The evolution of agricultural innovation system frameworks

Defining feature	NARS:	AKIS:	AIS:
Purpose	Planning capacity for agricultural research, technology development, and technology transfer	Strengthening communication and knowledge delivery services to people in the rural sector	Strengthening the capacity to innovate throughout the agricultural production and marketing system
Actors	1、National agricultural research organizations, 2、Agricultural universities or faculties of agriculture, 3、 extension services, 4、 farmers	1、National agricultural research organizations, 2、agricultural universities or faculties of agriculture, 3、extension services, 4、farmers, 5、NGOs, and entrepreneurs in rural areas	Potentially all actors in the public and private sectors involved in the creation, diffusion, adaptation, and use of all types of knowledge relevant to agricultural production and marketing
Outcome	Technology invention and technology transfer	Technology adoption and innovation in agricultural production	Combinations of technical and institutional innovations throughout the production, marketing, policy research, and enterprise domains
Organizing principle	Using science to create new technologies	Accessing agricultural knowledge	New use of knowledge for social and economic change
Mechanism for innovation	Transfer of technology	Interactive learning	Interactive learning
Degree of market integration	Nil	Low	High
Role of policy	Resource allocation, priority setting	Enabling framework	Integrated component and enabling framework
Nature of capacity strengthening	infrastructure and human resources for scientific research	communication between actors in rural areas	interactions between actors; creating and enabling environment

Source: Adapted from World Bank 2006

2.2. The Agricultural Innovation System: A Conceptual Framework

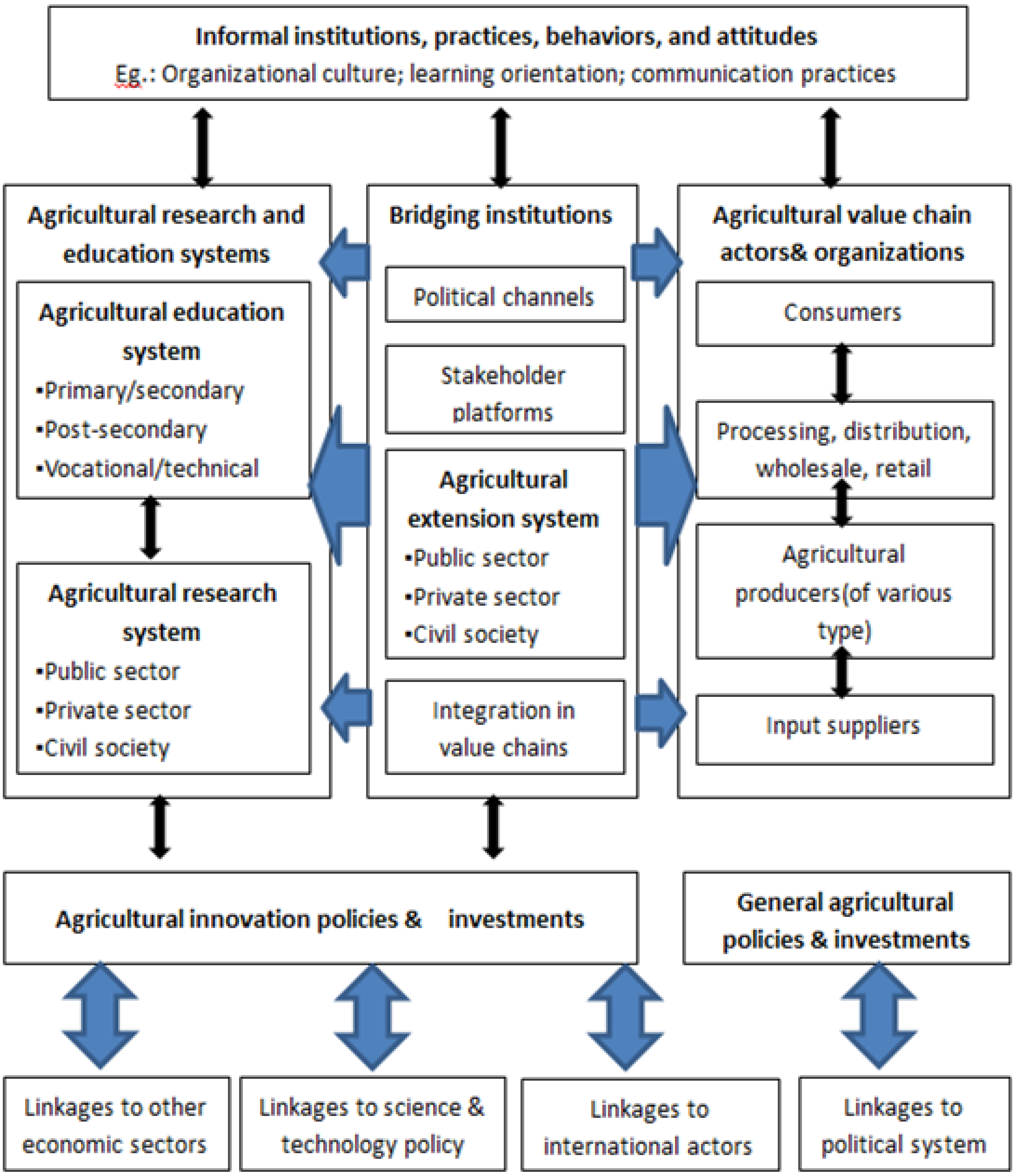
This section explores the concept of agricultural innovativeness in developing countries by using the agricultural innovation system framework. The fundamental elements of a national agricultural innovation system, the linkages between the components and the institutions and policies that constitute the enabling environment for innovativeness, are included in the conceptual framework. Figure 1 presents a conceptual framework of the agricultural innovation system based on Arnold and Bell (2001). The framework captures two main elements: the knowledge and education domain and the business and enterprise domain, and the linkage between these two components is formed by the bridging institutions. In the bottom of the framework is the conditions that affect the innovativeness, namely the enabling environment.

The left-hand side of figure 1 is the knowledge and education domain, this domain consists of agricultural research and the education system. This domain plays a key role in the agricultural innovation system as it is responsible for the development and dissemination of knowledge. There are two types of knowledge: scientific and local. Scientific knowledge comes from academic research while local knowledge is the product of accumulated experience. Knowledge development promotes agricultural innovativeness. The right-hand side of Figure 1 is the business and enterprise domain. This domain includes the agricultural value chain actors and organizations. Between these two domains is the bridging institution domain. Bridging institutions facilitate the transfer of knowledge and information. This domain consists of political channels, stakeholder platforms and extension services.

Then we introduce the working modus about the agricultural innovation system: first, the experts and researchers in the knowledge and education domain build hypothesizes and verify them, and then publish articles. Second, with the help of the bridging institution domain, the business and enterprise domain use the output of the knowledge and education domain to innovate independently.

The enabling environment domain describes the circumstances around the agricultural innovation system. This domain comprises agricultural innovation policies and investments as well as some informal institutions. A positive environment can foster innovation while a negative one will impede its development.

Figure 1: A Conceptual Framework of a National Agricultural Innovation System



Source: Spielman and Birner (2008); adapted from Arnold and Bell 2001

2.3. Agricultural Innovation Indicators

This section presents the toolkit explored by Spielman and Keleme (2009) to introduce indicators of innovativeness. Innovation indicators are based on the four domains of the conceptual framework for agricultural innovation systems: the knowledge and education domain, the business and enterprise domain, the bridging institutions domain and the enabling environment domain.

In order to identify the type of indicators that can be used to measure the agricultural innovation system's performance, this section adopts several criteria for selecting indicators. First, the indicators should be measureable; second, the indicators we choose should be relevant to agricultural innovativeness in developing countries; moreover, the data of the indicators must be available. The innovation indicators will be introduced separately for the different domains of the conceptual framework.

(1) The Knowledge and Education Domain

There are three indicators that are commonly used to describe this domain: public-sector agricultural R&D expenditure, the number of scientific journal articles and education enrollment. The first indicator is also called the agricultural R&D intensity and it represents financial investment in agricultural R&D in developing countries. The number of scientific journal articles is a proxy for productivity of agricultural R&D. Education enrollment gives an idea of the level of education in a country. It is an important standard of examining a country's educational development.

(2) The Business and Enterprise Domain

Indicators in this domain can be divided into two groups: one influences the nature and performance of business and business innovation in the agricultural sector, the other enables business and business innovation in agriculture through the quality of institutions and infrastructure. In first area, net inflows of foreign direct investment (FDI) play a vital role in innovativeness in agricultural sectors in developing countries. In the second area, two indicators are commonly used: the number of telephone lines and mobile cellular subscriptions and the extent of the road network as an indicator of the enabling infrastructure that can support businesses and enterprises in the agricultural sector. Telephone and road networks have a close relation with the extent of the rural market development. These indicators are consistent with Spielman and Keleme (2009) and Mekonnen et al. (2012).

(3) The Bridging Institutions Domain

This domain is the linkage between the knowledge and education domain and the business and enterprise domain. Indicators in this domain are difficult to come by. Considering the data used by Mekonnen et al. (2012), a press freedom index and health expenditures can be used as proxies of media which can connect the knowledge and education domain and the business and enterprise domain.

(4) The Enabling Environment Domain

Two types of indicators are used in this domain：Property rights in agriculture which support investments in innovation and governance institutions or policies that make contributions to agricultural innovation. Indicators that describe the enabling environment include net official development assistance, and level of corruption. The former provides a proxy for public investment in agricultural markets (Sipelman and Kelemework 2009), while the latter represents the quality of governance(Kaufmann, Kraay et al. 2005).

Furthermore, rural population density may influence the technical efficiency in agricultural production in developing countries. Although this indicator is only loosely related to the enabling environment, it is relevant as an indicator of redundant labor in rural areas in developing countries (Mekonnen et al. 2012).

This chapter has reviewed the evolution of the agricultural innovation systems approach and presented the framework of the agricultural innovation system. We also introduced the indicators that can describe the framework. These indicators will be used with the conventional input indicators as variables in the production functions in chapter 3.

3. Model Specification and Data

This chapter provides the econometric methodology and the hypothesis used in the econometric estimation. And the data used in the econometric analysis are also discussed in this chapter. Stochastic frontier analysis (SFA) is a method to estimate the technical efficiency based on the estimation of production function and separation of technical inefficiency and random errors. SFA has been applied in a considerable number of empirical studies in agricultural economics, especially to estimate the technical efficiency of the agricultural sector. We choose the stochastic frontier approach to reach the target of this thesis. SFA is appropriate because the agricultural sector of a country is subject to heterogeneous environmental factors. After the introduction of the stochastic frontier production function and the variables that will be used in the estimation, the expected signs of explanatory variables in the technical efficiency equation and the data used will be discussed.

3.1 A Stochastic Frontier Production Function

The stochastic frontier approach was first proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), and it has made a significant contribution to the econometric modeling of production and the estimation of technical efficiency(Battese 1992).

Battese and Coelli (1995) improved the model on the basis of previous studies; they introduced the concept of time, so that the SFA model can evaluate the technical efficiency of panel data. They give the following specification of a standard stochastic frontier production function(Battese and Coelli 1995):

$$Y_{it} = \exp(X_{kit}\beta + V_{it} - U_{it}) \qquad (1)$$

Where in equation (1), Y_{it} is the output for the i^{th}observation at time t. X_{kit} means the (1*K) vector of inputs for the i^{th}observation at time t. β is a (1*k) vector of parameters of the model to be estimated. This function not only includes the inputs used in production, but also involves a random disturbance term, which is composed by random errors and non-negative errors. V_{it} is random errors and U_{it} is non-negative random variable. V_{it} is random errors, independently distributed of theU_{it} . U_{it} is random variable associated with the technical inefficiency of production; and it is independently distributed.

Following equation (1), the production function for country i to be estimated is specified as:

$$\ln(Y_{it}) = \beta_0 + \sum_k \beta_k \ln x_{kit} + \frac{1}{2}\sum_k \sum_j \beta_{kj} \ln x_{kit} \ln x_{jit} + \sum_k \alpha_k \ln x_{kit}\, t + \gamma_t t + \gamma_{tt} t^2 + \sum_i^{i-1} \theta_i D_i + V_{it} - U_{it} \qquad (2)$$

In equation (2), β is a (1*k) vector of parameters of the model to be estimated. i represents the country, while t indicates the year of observation. $\ln(Y_{it})$ is the logarithm of the value of net agricultural production. x_{kit} are inputs used for agricultural production. The input variable x_{kit} includes fertilizer (N, P, and K), labor use, land and live animals. This equation not only includes the general variables such as the inputs of the production but also includes a time trend t, its square and its interaction with the production inputs. Country-specific variables, like climate and market access, are represented by the dummy variablesD_1, D_2 and D_3 for East Asia, Southeast Asia and South Asia, respectively. The reason why we choose a translog specification is that the translog specification represents a second-order approximation to any true function form and it places fewer restrictions on the estimation than a Cobb-Douglas specification or other more traditional specification (Tan, Heerink et al. 2010). V_{it} is a vector of random errors and U_{it} is a non-negative random variable. V_{it} and U_{it} are independently distributed of U_{it} .

The technical inefficiency effect U_{it} (Mekonnen et. al 2012) can be specified as equation (3):

$$U_{it} = Z_{it}\delta + t + W_{it} \qquad (3)$$

The technical efficiency of production for country i at time t becomes:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - t - W_{it}) \qquad (4)$$

Technical efficiency scores describe the relationship between the input and output, in equation (4), TE_{it} represents the efficiency scores of each country obtained from equation (2). t is the time trend While W_{it} is the truncation with zero mean and variance. Z_{it} represents the indicators from the different domains of the agricultural innovation system and may influence the technical efficiency. In other words, Z_{it} describes the level of agricultural innovativeness in the countries under consideration. This thesis uses Z_{it} variables to influence the stochastic component of the production frontier directly through estimating equation (2) and (4) simultaneously.

3.2 Explanatory variables and hypotheses

The variables used in the empirical analysis of technical efficiency are the indicators that can describe the performance of a country's agricultural innovation system, as explained in chapter 2. Considering the availability of data, the following indicators will be used to analyse the technical efficiency:

(1) For the knowledge and education domain: public-sector agricultural R&D expenditure, education enrolment and the number of scientific journal articles. While the education enrolment means the gross enrolment ratio (%) and it can exceed 100% because of the inclusion of over-aged and under-aged students (World Bank 2014)
(2) For the business and enterprise domain: the number of telephone lines and mobile cellular subscriptions (per 100 people), total road network (km), and net inflows of foreign direct investment (current US$).
(3) For the bridging institutions domain: health expenditures.
(4) For the enabling environment domain: net official development assistance, and the rural population density as a share of total population (%).

The hypotheses of the explanatory variables used in the technical efficiency equation (4) are presented in table 2.

Table 2: Explanatory variables and their expected effect on technical inefficiency

Variable	Unit	Expected effect on technical inefficiency
Knowledge and Education Domain		
agricultural R&D expenditure	US$	-
Education enrolment	%	-
Scientific journal article	number	-
Business and Enterprise Domain		
Telephone lines	Number/100 people	-
Total road network	km	-
Foreign direct investment	US$	+/-
Bridging Institutions Domain		
Health expenditure	US$	-
Enabling Environment Domain		
Net official development assistance	US$	+/-
Rural population density	%	-/+

As all three variables in the knowledge and education domain can foster the development of agriculture and promote agricultural production (Mekonnen et al 2012), we expect that all three variables reduce technical inefficiency. In the business and enterprise domain, the telephone and total road network are expected to reduce technical inefficiency unless such investments neglect the rural areas. This expectation is in line with Spielman and Keleme (2009). However, it is hard to say whether the impact of FDI will be positive or negative. FDI can reduce the transfer costs of knowledge and technologies on the one hand, but on the other hand, FDI can also cause resource reallocation from agriculture to other sectors (Mekonnen et al 2012). Mekonnen et al (2012) also point out that sectoral bias exists in the foreign direct investment such as mining and oil exploration and, as a result, public priorities and resource allocations may transfer from agriculture to other sectors. In the bridging institutions domain, health expenditures are expected to reduce inefficiency. Improved living standards through higher investments in health can indirectly influence agricultural development. For the enabling environment domain, the net official development assistance may reinforce public sector commitment to agriculture but it can also have a crowding-out effect. Hence, the impact of net official development assistance on inefficiency is mixed. The rural population is included to capture the effect of redundant labour in the agricultural sector. The expected effect is ambiguous.

3.3 Data Collection and Descriptive Statistics

This chapter discusses the data and data sources for the input and innovation indicators for developing countries' agriculture. This chapter also presents the descriptive statistics for the variables used in the stochastic frontier analysis.

3.3.1 Sampling and Data Collection

The stochastic frontier production functions (2) and (3) are defined for panel data of 14 developing countries in Asia between 2002 and 2010. The data were collected from the Food and Agricultural Organization of the United Nation's FAOSTAT and the World Bank.

Following Mekonnen et al (2012), this study defines the dependent variable y_{it} as the value of net agricultural production in international dollars. The data is derived from FAOSTAT. The prices of international commodity come from this source can avoid the use of nominal exchange rates. Data we collected from this website has no relationship between the price of each commodity and the country where it was produced.

The inputs to agricultural production cover fertilizer, land, labor and live animals and the data for these inputs is obtained from the FAOSTAT and World Bank. Fertilizer consumption measures the quantity of plant nutrients used per unit of land (World Bank 2013). Fertilizers are mainly divided into three basic types: nitrogen fertilizers (N), phosphate fertilizers (P205) and potash fertilizers (K20). Fertilizer use is recorded by FAOSTAT on a calendar-year basis. Fertilizer use is measured in terms of the quantity (in metric tons) of consumption of nutrients by a country in a specific year. Land is measured in terms of arable land and permanent crops in thousand hectares (1000ha) in a given year. Previous studies have also used the number of tractors as an indicator of inputs. However, according to the FAOSTAT and the World Bank, between the years 2005-2011, the data for this indicator is not available anymore, so this paper doesn't choose tractor as an indicator. Agricultural labor is measured as the total economically active population in agriculture (per 1000 heads). Labor data is obtained from FAOSTAT. The data of the stocks of live animals were also obtained from FAOSTAT. Animals were counted in heads except for bees which are measured in number of beehives. In order to aggregate different stocks of live animals, we use conversion factors to convert different stocks of live animals into livestock units.

Data sources for the variables that explain the character and performance of agricultural innovation systems include: World Bank – for data on health expenditures, roads and telephone network, FDI, rural population, net official development assistance, and the education enrollment; ASTI for data about the number of scientific journals and public sector agricultural R&D intensity.

3.3.2 Descriptive Statistics

Table 3 provides summary statistics for the variables used in the estimation. The mean agricultural output of the 14 countries was about 60 million dollars but there were large variations among countries. Average use of nitrogen fertilizers (N), phosphate fertilizers (P205) and potash fertilizers (K20) is 4 million, 1.5 million, and 755 thousand tons respectively. The average land used for agriculture was around 27 million ha. Labor use varied from 112 to more than 500 thousand heads. And the average number of animals is about 140 million.

Table 3. Descriptive statistics of variables in the model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Values of production function variables					
Output (10^7US$)	126	5.89	11.4	0.09	48.3
Nfert (10^6 tons)	126	4.10	9.08	0.002	45.1
Pfert (10^6 tons)	126	1.47	3.33	0.001	14.4
Kfert (10^5 tons)	126	7.55	16.0	0.004	84.7
Labor (10^4)	126	6.80	13.8	0.011	51.0
Land (10^6 ha)	126	26.7	46.4	0.140	160
Live animal (10^{10})	126	14.0	26.0	0.185	103
Values of technical efficiency model variables					
Knowledge and Education Domain					
agricultural R&D expenditure (10^2 US$)	126	4.79	8.58	0.05	36.3
Education enrolment (%)	126	52.54	142	0.06	799
Scientific journal article (number)	126	106	11.5	72.1	141
Business and Enterprise Domain					
Telephone lines (per 100 people)	126	10.21	9.02	0.44	35.09
Total road network (10^{10} km)	126	1.20	3.51	0.06	24.4
Foreign direct investment (10^5 US$)	126	6.25	12.2	0.07	45.8
Bridging Institutions Domain					
Health expenditure (US$)	126	4.36	1.69	1.92	9.68
Enabling Environment Domain					
Net official development assistance (US$)	126	19.58	36.66	0.073	256.74
Rural population density (%)	126	58	20	18	86
Including time trend					

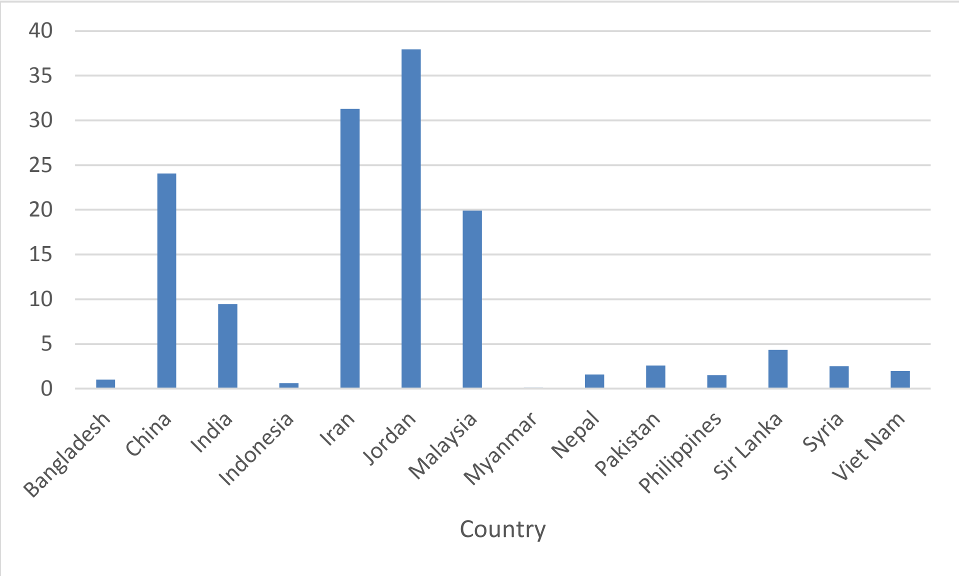
Source: own calculations based on the World Bank, FAOSTAT, ASTI

Table 3 also provides a description of the agricultural innovativeness indicators. The variation between countries is large, especially for the knowledge and education domain and the business and enterprise domain. In order to know how differences about the innovation indicators among the different countries, we give some relative indication instead of absolute indication such as agricultural R&D expenditure as a share of GDP, scientific articles per capita, FDI as a share of GDP, telephone lines per capita and road network per capita. As to see the differences clearly in figures, we use an index as Bangladesh equals 1(100%).

In the knowledge and education domain, figure 2 scientific journal articles per capita in different countries, we can see immediately that there is a large variation in this variables among different countries. Jordan has the biggest scientific journal articles per capita while Iran and China come in second and third.

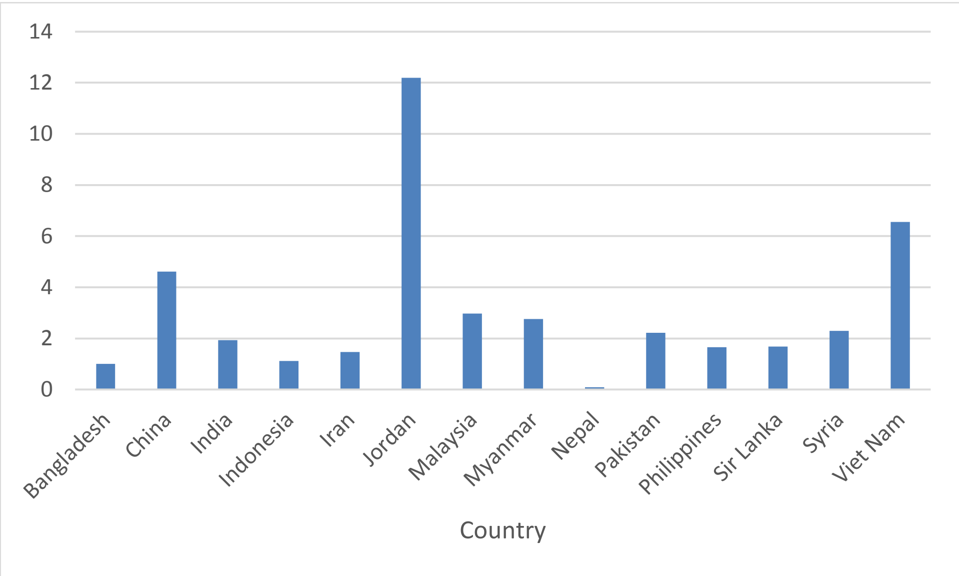
In the business and enterprise domain: Figure 3 shows that Jordan is far ahead of other countries in the foreign direct investment. While for the number of road network per capita in different countries, as shown in figure 4, are more complicated however Sir Lanka is superpower in road network.

Figure 2: scientific journal articles per capita in different countries



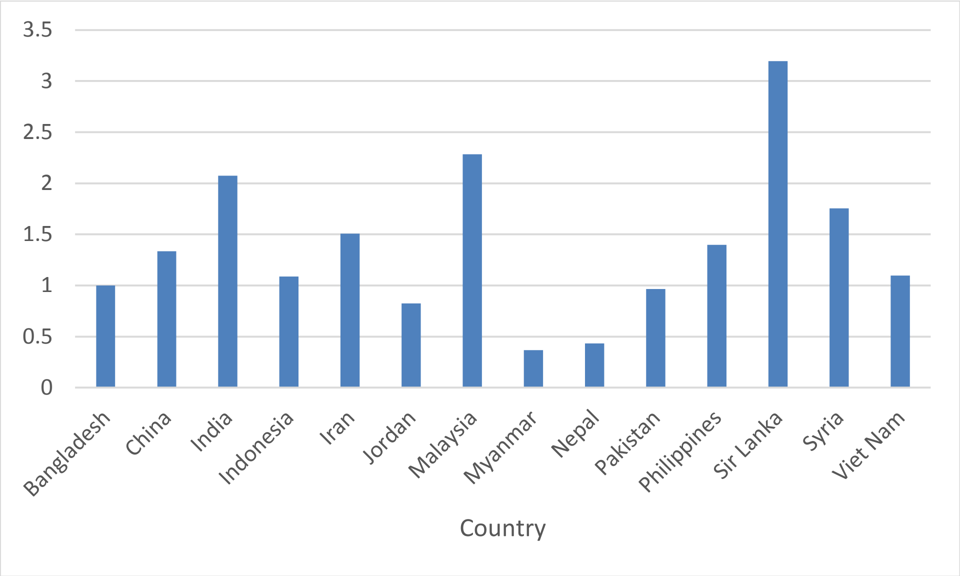
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure 3: FDI as a share of GDP in different countries



Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure 4: road total network per capita in different countries



Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A1-A5 in appendix A illustrates the mean values of the input variables used in the analysis between the year 2002 and 2010. A6 and A7 presents other innovation indicators among different countries.

4. Empirical results and discussion

This thesis employs the Frontier 4.1 software package and uses Maximum Likelihood(Coelli 1996) to estimate the SFA model. Table 4 shows the estimation results for equation (2) while table 5 presents the estimation results for equation (4).The results show that γ=0.987 and pass the t-test at 1 percent significant level. This illustrates that technical inefficiency affects random error terms at 96.3% level. Therefore, the stochastic frontier approach is effective. As LR=33.228, is larger than $\chi^2_{0.01}(9)=21.67$, technical inefficiency exist in the production function and the factors we choose to measure the agricultural innovation system are determinants of the technical efficiency. We can also say that the four domains including the education and knowledge domain, the business and enterprise domain, the bridging institutions domain and the enabling institutions domain all reject the null hypothesis at significance level 1% with LR=57.680 >$\chi^2_{0.01}(3)$, LR=26.885> $\chi^2(3)$, LR=16.449 >$\chi^2_{0.01}(1)$ and LR=22.604> $\chi^2_{0.01}(2)$. In what follows, we first discuss the results of the frontier functions and then discuss the results of the efficiency model.

4.1 Results of production frontier functions

Table 4 presents the estimated coefficients of the production frontier model with standard errors and t-ratio. The results show strong evidence that nitrogen and potash affect outputs, however their effects are different. We can also conclude that phosphate accompanied by enough potash decreases productivity. This indicates that with different types of fertilizer, the agricultural output responds differently. Labor affects agricultural output in a negative way, in contrast to findings of Mekonnen et al (2012). An explanation for this result can be the high number of rural population in most of Asian countries which provides a large rural surplus of labor and a decreasing the marginal effect of labor in these countries. Agricultural output increases with the expansion of land. This confirms that land is a vital input in agricultural production. Livestock is also an important input and positively affects agricultural output.

Table 4: Maximum Likelihood Estimates of the frontier function model

	Coeff	Standard-error	T-ratio	Sig.
Production frontiers				
Constant	-9.386	0.978	-9.592	***
ln(Nfert)	-0.384	0.126	-3.047	***
ln(Pfert)	-0.070	0.114	-0.612	
ln(Kfert)	0.155	0.074	2.099	**
ln(labor)	-0.226	0.414	-5.460	***
ln(land)	0.221	0.659	3.348	***
ln(animal)	3.009	0.270	11.134	***
$\ln(Nfert)^2$	0.030	0.014	2.068	**
$\ln(Pfert)^2$	0.029	0.013	2.197	**
$\ln(Kfert)^2$	0.003	0.005	0.545	
$\ln(labor)^2$	-0.180	0.034	-5.276	***
$\ln(land)^2$	0.233	0.107	2.182	**
$\ln(animal)^2$	-0.104	0.022	-4.693	***
ln(Nfert)*ln(Pfert)	-0.056	0.050	-1.111	
ln(Nfert)*ln(Kfert)	0.018	0.027	0.689	
ln(Pfert)*ln(Kfert)	-0.043	0.027	-1.597	*
ln(labor)*ln(land)	-0.052	0.199	-0.262	
ln(labor)*ln(animal)	0.656	0.115	5.710	***
ln(land)*ln(animal)	-0.606	0.198	-3.066	***
ln(Nfert*t)	0.001	0.007	0.191	
ln(Pfert*t)	-0.003	0.008	-0.451	
ln(Kfert*t)	0.001	0.003	0.491	
ln(labor*t)	0.003	0.003	0.878	
ln(land*t)	-0.004	0.009	-0.443	
ln(animal*t)	0.002	0.009	0.263	
t	0.046	0.075	0.606	
t^2	-0.005	0.001	-3.416	***
Dummy1(East Asia)	1.510	0.115	13.140	***
Dummy2(Southeast Asia)	0.322	0.069	4.644	***
Dummy3(South Asia)	0.018	0.058	0.308	
Sigma-squared	0.009	0.001	7.231	***
Gamma	0.987	0.061	16.139	***
Log likelihood function=168.552				
LR test of one-side error=33.228				
No. of observations=126				

*, **, *** denote significant at 10%, 5%, and 1% levels, respectively

Source: own estimation based on World Bank, FAOSTAT, ASIT

The time dummies are positive, which suggests that there are technical improvements in agricultural productivity even though these variables are not statistically significant. The estimated coefficients of the country dummies for East Asia and Southeast Asia are positive and significantly different from zero. This illustrates that there are some differences in technical efficiency among different regions. The reason for this might be that East Asia is abundant in resources and has a good natural environment. Southeast Asia is one of the most dynamic regions in Asia and rural labor in this region is operating at a high technology level.

4.2 Results of technical efficiency models

Table 5 presents the results of the impact of the agricultural innovation system on technical efficiency which is described in equation (4).

All the variables in the knowledge and education domain are consist with the expected effects in reducing technical inefficiency. The number of scientific journal articles published by researchers was found to have statistically significant negative effects on technical inefficiency. Agricultural R&D expenditures and primary school enrolment also had a negative effect on technical inefficiency but these effects are not statistically significant.

Foreign direct investment in the business and enterprise domain has a statistically negative impact on technical inefficiency. This result does not confirm the finding made by Mekonnen et al (2012) that foreign direct investment can exacerbate agricultural inefficiency. Telephone networks and road networks did not have the excepted result of enhancing agricultural efficiency and they are statistically significant at 5 and 10 percent significance levels, respectively.

Health expenditures – in the bridging institutions domain – do not show a significant effect in reducing technical inefficiency.

In the enabling environment domain, rural population density was found to be statistically significant at 10 percent level. The negative effect of the rural population density on technical inefficiency implies that it decreases the inefficiency. The positive sign of net official development assistance means that more aid leads to less efficiency. However, this variable is not statistically significant.

In general, all the variables in knowledge and education domain and foreign direct investment in the business and enterprise domain are important to improve technical efficiency. While education enrolment has the highest potential to improve efficiency in developing countries.

Table 5: efficiency effects from the AIS framework

	Coeff	Standard-error	T-ratio	Sig
Technical inefficiency				
Knowledge and Education Domain				
agricultural R&D expenditure	-0.006	0.060	-0.102	
Education enrolment	-0.085	0.043	-1.982	**
Scientific journal article	-0.102	0.203	-0.500	
Business and Enterprise Domain				
Telephone networks	0.080	0.048	1.665	**
Total road network	0.081	0.017	-2.026	***
Foreign direct investment	-0.034	0.062	1.314	*
Bridging Institutions Domain				
Health expenditure	-0.019	0.029	-0.667	
Enabling Environment Domain				
Net official development assistance	0.014	0.026	0.541	
Rural population density	-0.282	0.024	-1.382	*

Statistical significance levels: 10% ’*’, 5% ’**’, 1% ‘***’

Source: own estimation based on World Bank, FAOSTAT, ASIT

4.3 Technical efficiency scores

Table 7 shows the technical efficiency scores for the sample. The average technical efficiency is about 88 percent. This implies that on average these countries still have 12 percent potential to increase their agriculture productivity. Although the agricultural technical efficiency falls a little in the years 2004 and 2008, overall we observe an upward trend. Figure 5 shows that the evolution of average technical efficiency scores can be divided in three periods. During the first period, from 2002 to 2005, the average efficiency peaked at 89.3 percent in 2004 but reach a low point of 85.7 percent in the next year. Between 2006 and 2008, the technical efficiency decreased from 88.8 percent to 88.0 percent. The technical efficiency rose steadily from 2008 to 2010. The mean efficiency score has an increase from 88.2 percent in the year 2002 to 91.0 percent in 2010.

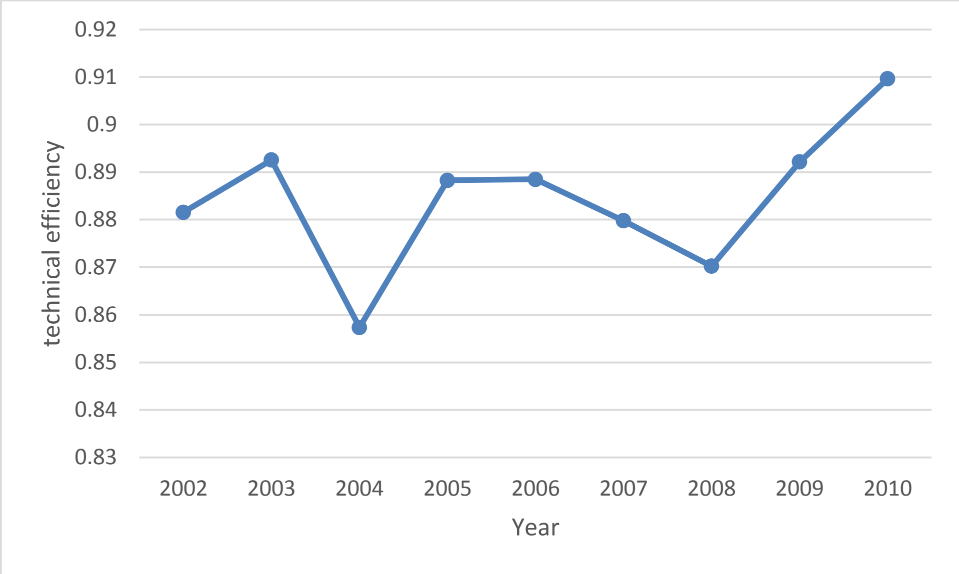
Among the countries in the sample, the efficiency scores in countries such as Bangladesh, China, India, Iran, Jordan, Pakistan and Vietnam are around 90 percent and stay constant over the time period. Countries like Bangladesh, India, Iran, Jordan, Pakistan and Vietnam with higher average efficiency scores are less developed countries and have the highest potential for improvement. However, these countries may have limited room for improving the output under the existing condition because of the high technical efficiency scores, so they'd better focus on the amount of input in order to push the production frontier outward. Myanmar gained about 23 percent in technical efficiency during the 9 years under consideration. Next is Malaysia, which increased 17 percentage efficiency scores. These two countries also started at a low level of efficiency scores. In contrast, the efficiency of Philippines has fallen to 77.2 percent from 95.5%, and Sir Lanka lost 17 percentage point in efficiency scores within the same period. Table 6 also shows some countries like Indonesia and Syria that have low efficiency scores and do not have an obvious increase during 2002 to 2010. Syria, with mean efficiency score of 78.4 percent, is the most inefficient country among these 14 countries. These countries should realize they still have a substantial potential to increase technical efficiency, e.g., by improving education or making improvement in telephone and road networks.

Table 6: technical efficiency scores

	2002	2003	2004	2005	2006	2007	2008	2009	2010	mean
Mean efficiency (2002-2010):				0.884						
Mean	0.882	0.893	0.857	0.888	0.889	0.880	0.870	0.892	0.910	
Bangladesh	0.896	0.904	0.849	0.898	0.924	0.952	0.904	0.959	0.951	0.915
China	0.973	0.970	0.994	0.963	0.936	0.993	0.983	0.966	0.987	0.974
India	0.957	0.993	0.934	0.933	0.953	0.995	0.994	0.976	0.980	0.968
Indonesia	0.756	0.883	0.712	0.816	0.868	0.805	0.776	0.799	0.807	0.802
Iran	0.993	0.967	0.845	0.924	0.839	0.901	0.745	0.892	0.982	0.899
Jordan	0.915	0.892	0.991	0.904	0.828	0.848	0.989	0.985	0.986	0.926
Malaysia	0.720	0.930	0.929	0.980	0.982	0.915	0.880	0.940	0.890	0.907
Myanmar	0.717	0.797	0.677	0.869	0.861	0.804	0.954	0.963	0.948	0.843
Nepal	0.870	0.911	0.875	0.948	0.986	0.894	0.751	0.874	0.852	0.885
Pakistan	0.894	0.847	0.873	0.841	0.837	0.884	0.993	0.930	0.942	0.893
Philippines	0.955	0.877	0.855	0.842	0.830	0.831	0.868	0.772	0.772	0.845
Sir Lanka	0.956	0.943	0.873	0.758	0.778	0.793	0.720	0.784	0.743	0.806
Syria	0.834	0.714	0.765	0.820	0.875	0.778	0.647	0.709	0.910	0.784
Viet Nam	0.906	0.868	0.831	0.940	0.942	0.924	0.979	0.941	0.985	0.924

Source: own estimation based on World Bank, FAOSTAT, ASIT

Figure 5: Evolution of average levels of agricultural technical efficiency during 2002-2010



Source: Own estimations based on World Bank, FAOSTAT, ASTI

5. Concluding remarks

Agriculture accounts for a significant share of economic activities in most developing countries. Increasing agricultural productivity is therefore of a crucial importance for improving the GDP and the livelihoods of households in most developing countries. However, the agricultural innovativeness is an important factor that can affect this respect.

This thesis estimated the level of technical efficiency of 14 developing countries in Asia between the year 2002 and 2010 by using a stochastic frontier production function to explore the role does agricultural innovativeness paly in explaining agricultural technical efficiency in developing countries. We use the indictors which can describe the different domain of agricultural innovation systems framework (the knowledge and education domain, the business and enterprise domain, the bridge institution domain and the enabling environment domain) to determine the level of technical inefficiency. And we simultaneously estimated the production function and the inefficiency by use of Frontier 4.1 software package. The purpose of this thesis is to investigate the impact of agricultural innovativeness on agricultural productivity. The likelihood ratio test was used to estimate the Translog production function and the efficiency model. The test revealed these two models are all fit of the data.

The overall average technical efficiency score of the countries under has shown a tortuous increase from 88.2 percent in the year 2002 to 91.0 percent in 2010.The estimated result of the sampled countries suggest that if they reallocation of the existing resources then they still have room for increase of agricultural production. Despite the statistically significant differences in technology levels among the sampled countries and according to the technical efficiency scores of these countries we can conclude that although some least developed countries like Bangladesh, Jordan, Pakistan and Vietnam with upper technical efficiency scores. This implies this type country is limited under existing agricultural innovativeness. They should focus on the indictors which can push the frontier of the production outward in the long run. There are also some countries like Indonesia and Syria which have relatively low efficiency scores need to focus on the indicators that affect the different domains of agricultural innovation systems framework.

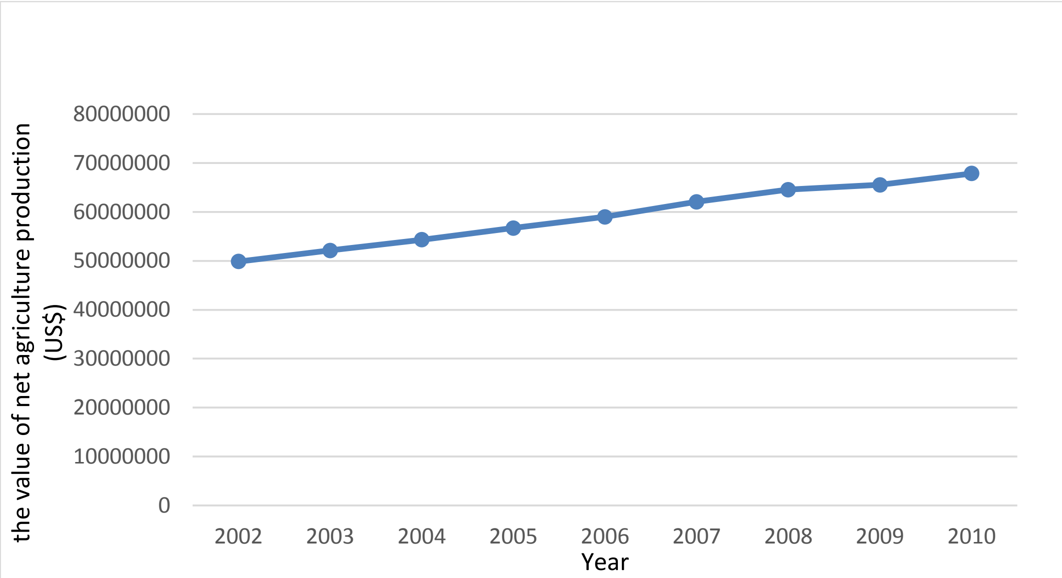
In the knowledge and education domain, the number of scientific journal articles are found to be the significant factors in explaining technical efficiency among different countries. The factors in this domain including Agricultural R&D expenditure, education enrollment and the number the scientific journal articles can reduce technical inefficiency. High rural population density in enabling environment domain were also found to be efficiency enhancing.

One of the limitations of this thesis is that the data for some of the innovation system variables is unavailable so we just use the available data to describe the agricultural innovativeness. For a few missing data, we estimated the average the year before and after. The other limitation is that some variables such as scientific journal articles are not specific to agriculture.

Appendix A: Variables Description

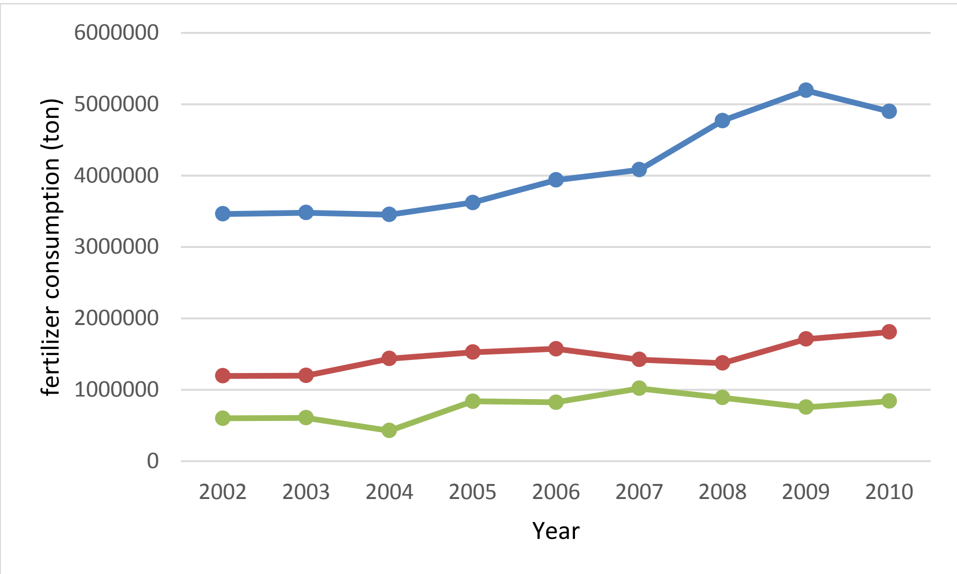
Average output for the 14 countries in Asia increased from the year 2002 to 2010. Nitrogen fertilizer (N) slowly increased between the year 2002 and 2007, but it has a dramatically increased in the next two years. Between 2009 and 2010, there is a decrease for this fertilizer. Phosphate fertilizer (P205) and potash fertilizer (K20) are stay constant. From the year 2002 to 2010, the labor and animal inputs maintain stable growth. In spite of these years volatility in the land input. The underlying trend for a decade has been for it to stay constant at the level of 27 thousand (1000Ha).

Figure A 1: Trend of the mean output during 2002-2010



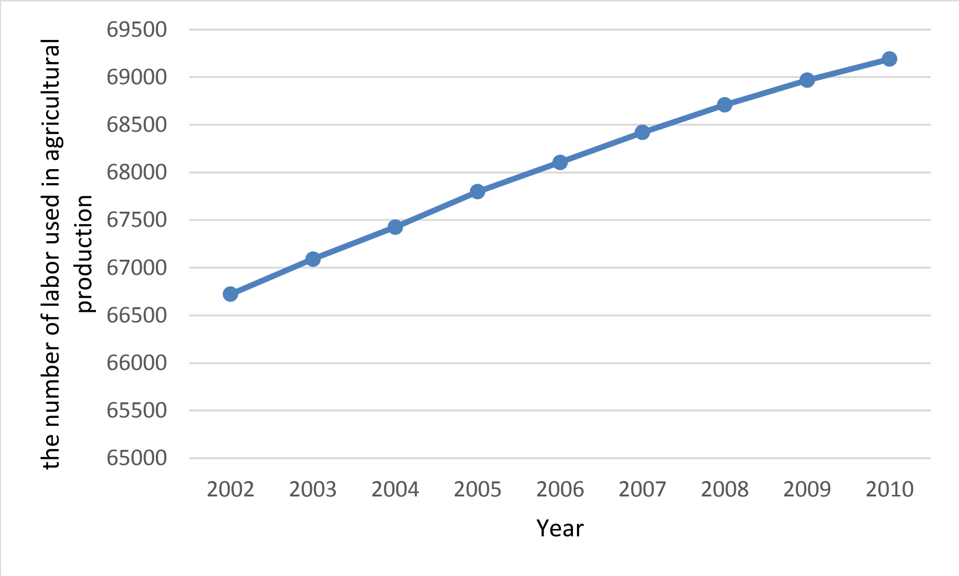
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A 2: the change trend of the fertilizer consumption during 2002-2010



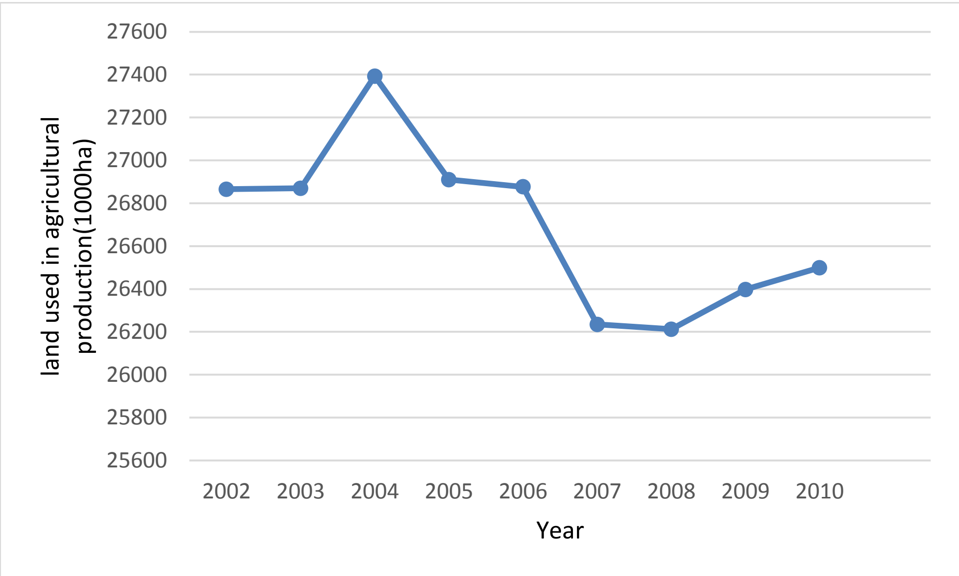
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A 3: the change trend of the labor use during 2002-2010



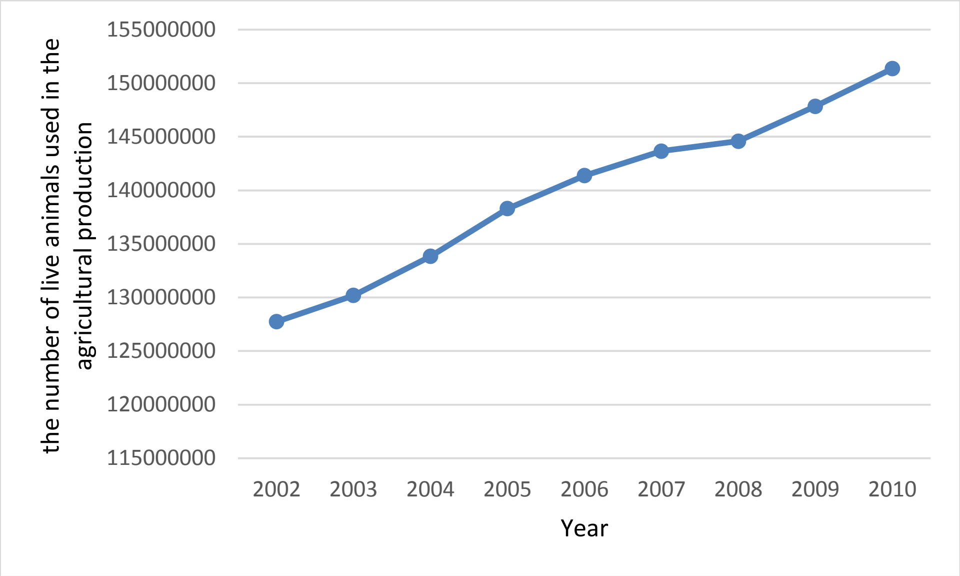
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A 4: the change trend of the land use during 2002-2010



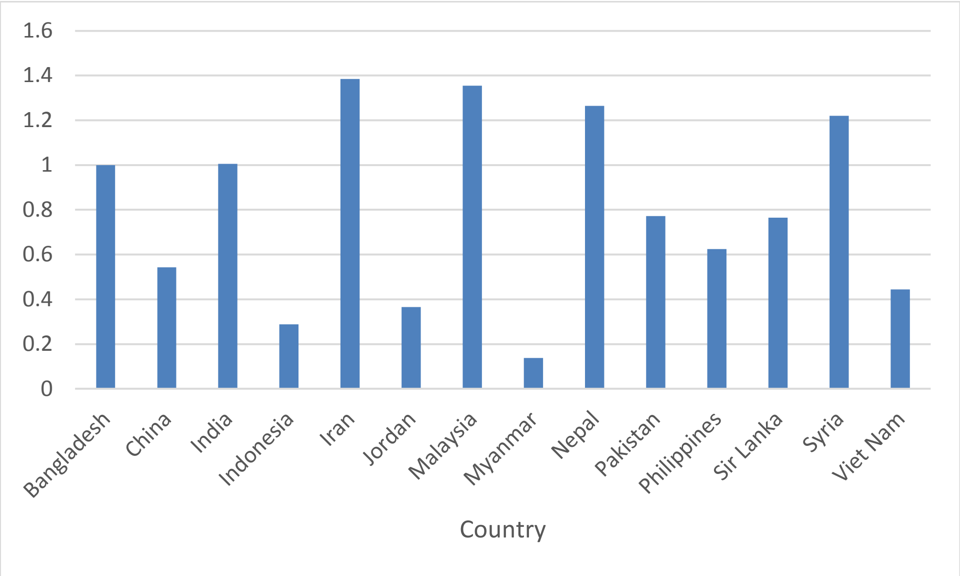
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A 5: the change trend of the living animals during 2002-2010



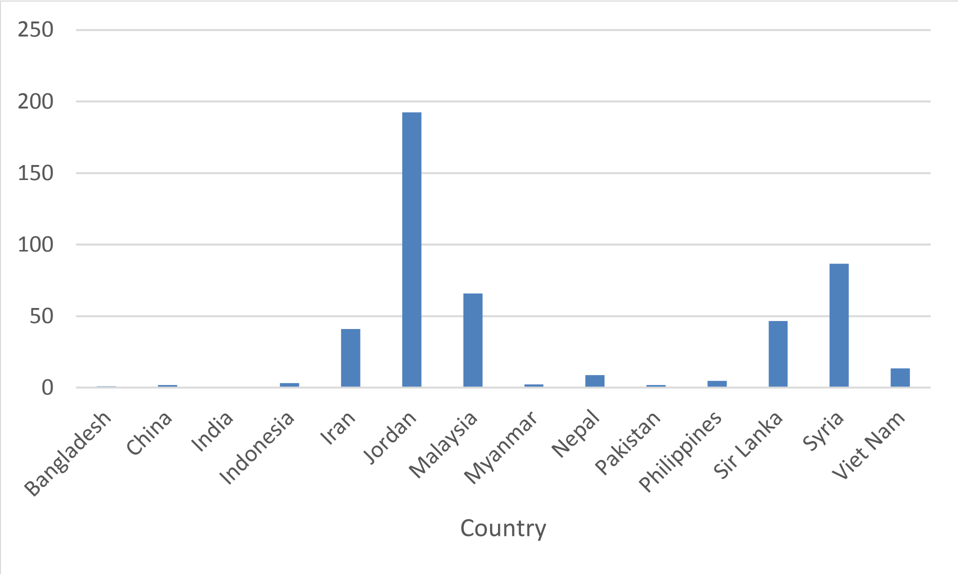
Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A6: Agricultural R&D expenditure as a share of GDP in different countries



Source: Own estimations based on World Bank, FAOSTAT, ASTI

Figure A7: telephone lines per capita in different countries.



Source: Own estimations based on World Bank, FAOSTAT, ASTI

Appendix B: The Original Output of Frontier 4.1

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	-0.93861608E+01	0.97858484E+00	-0.95915658E+01
beta 1	-0.38384997E+00	0.12595783E+00	-0.30474484E+01
beta 2	-0.69652731E-01	0.11374838E+00	-0.61234039E+00
beta 3	0.15513624E+00	0.73898372E-01	0.20993188E+01
beta 4	-0.22583123E+01	0.41359017E+00	-0.54602658E+01
beta 5	0.22066591E+01	0.65902032E+00	0.33483931E+01
beta 6	0.30094224E+01	0.27030309E+00	0.11133511E+02
beta 7	0.29825064E-01	0.14421158E-01	0.20681463E+01
beta 8	0.28859099E-01	0.13134234E-01	0.21972426E+01
beta 9	0.25996918E-02	0.47672371E-02	0.54532463E+00
beta10	-0.17952208E+00	0.34028264E-01	-0.52756757E+01
beta11	0.23257353E+00	0.10657696E+00	0.21822121E+01
beta12	-0.10416826E+00	0.22194424E-01	-0.46934429E+01
beta13	-0.55604006E-01	0.50027105E-01	-0.11114776E+01
beta14	0.18387766E-01	0.26669662E-01	0.68946380E+00
beta15	-0.43355861E-01	0.27151010E-01	-0.15968416E+01
beta16	-0.52282459E-01	0.19933638E+00	-0.26228258E+00
beta17	0.65638142E+00	0.11512442E+00	0.57014958E+01
beta18	-0.60561358E+00	0.19754632E+00	-0.30656788E+01
beta19	0.14375549E-02	0.74940154E-02	0.19182705E+00
beta20	-0.34196445E-02	0.75830567E-02	-0.45095858E+00
beta21	0.14902690E-02	0.30374017E-02	0.49063942E+00
beta22	0.30258394E-02	0.34446993E-02	0.87840449E+00
beta23	-0.38436242E-02	0.86834248E-02	-0.44263921E+00
beta24	0.22445988E-02	0.85224174E-02	0.26337584E+00
beta25	0.45606106E-01	0.75266157E-01	0.60593110E+00
beta26	-0.45133937E-02	0.13211007E-02	-0.34163889E+01
beta27	0.15097621E+01	0.11490154E+00	0.13139615E+02
beta28	0.32167381E+00	0.69273654E-01	0.46435231E+01
beta29	0.17961740E-01	0.58255733E-01	0.30832570E+00
delta 0	0.90020979E+00	0.10122069E+01	0.88935352E+00
delta 1	-0.60733032E-02	0.59676438E-01	-0.10177054E+00
delta 2	-0.84990671E-01	0.42871408E-01	-0.19824558E+01
delta 3	-0.10177520E+00	0.20338182E+00	-0.50041443E+00
delta 4	-0.33824409E-01	0.16695406E-01	-0.20259711E+01
delta 5	0.79833938E-01	0.47949117E-01	0.16649720E+01
delta 6	0.81486377E-01	0.62004213E-01	0.13142071E+01
delta 7	0.13812692E-01	0.25522181E-01	0.54120345E+00
delta 8	-0.19322311E-01	0.28971396E-01	-0.66694444E+00
delta 9	-0.28225426E+00	0.20426059E+00	-0.13818342E+01

delta10 0.16275056E-02 0.14860949E-01 0.10951559E+00
sigma-squared 0.87425492E-02 0.12090402E-02 0.72309828E+01
gamma 0.98688880E+00 0.61148362E-01 0.16139252E+02
log likelihood function = 0.16855220E+03
LR test of the one-sided error = 0.33227716E+02
with number of restrictions = *

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