AN ANALYSIS OF TECHNICAL EFFICIENCY OF CROP FARMS IN THE NORTHERN REGION OF VIETNAM

by

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Canberra, September 2013
ABSTRACT

Vietnamese agriculture is dominated by small-scale farm households. The diversified cropping system is common in northern Vietnamese agriculture. Farms have been transformed since independence, from self-sufficient systems that produced mainly rice, to diversified farming systems, which now produce and market a large variety of products. This thesis aims at identifying the determinants of technical efficiency of farm households. The approach of this thesis offers some other important innovations over previous Vietnamese studies. Technical efficiency estimates are measured for diversified crops rather than individual crops. This is important because, a major challenge in examining production of farm households is crop diversification.

The investigation of determinants of technical efficiency should inform diversification policy for Vietnamese agriculture, especially from the base of rice production and assist in a better understanding of the behaviour of farmers using land for annual crops. The results of this paper indicate the importance of crop diversification. Farms favouring market-oriented products, such as annual industrial crops, have greater efficiency than farms focusing on staple crops such as rice and maize. The results also suggest that technical efficiency varies directly with farm size, off-farm income while it varies inversely with the extent of land fragmentation and use of family labour.
ACKNOWLEDGEMENTS

I received assistance and support from a number of sources during my study and throughout the time this thesis was being prepared.

I wish to thank the University of Canberra for providing outstanding institutional support. I also acknowledge the financial support from the Vietnamese Government.

I would especially like to thank my supervisors, Professor Phil Lewis, Dr Tesfaye Gebremedhin and Mr Greg Barrett, for their consistent guidance, encouragement and invaluable support throughout the progress of my study and for their supervision in the preparation of this thesis.

I would like to take this opportunity to thank my colleagues, who readily provided me with encouragement and professional advices.

Finally, to my family and friends, I sincerely thank all of you for your faith and support. Special thanks go to my parents (Van Nguyen and Dung Dao) and my daughters (Anh Bui and Uyen Bui) who have assisted and encouraged me during my doctoral program.
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE</td>
<td>Allocative Efficiency</td>
</tr>
<tr>
<td>CRS</td>
<td>Constant Returns to Scale</td>
</tr>
<tr>
<td>DEA</td>
<td>Data Envelopment Analysis</td>
</tr>
<tr>
<td>DRS</td>
<td>Decreasing Returns to Scale</td>
</tr>
<tr>
<td>EA</td>
<td>Enumeration Area</td>
</tr>
<tr>
<td>EE</td>
<td>Economic Efficiency</td>
</tr>
<tr>
<td>IRS</td>
<td>Increasing Returns to Scale</td>
</tr>
<tr>
<td>NIRS</td>
<td>Non-increasing returns to scale</td>
</tr>
<tr>
<td>OLS</td>
<td>Ordinary least squares</td>
</tr>
<tr>
<td>TE</td>
<td>technical Efficiency</td>
</tr>
<tr>
<td>TE(_{\text{CRS}})</td>
<td>total technical efficiency</td>
</tr>
<tr>
<td>TE(_{\text{VRS}})</td>
<td>pure technical efficiency</td>
</tr>
<tr>
<td>VARHS</td>
<td>Vietnam Access to Resource Household Survey</td>
</tr>
<tr>
<td>VGSO</td>
<td>Vietnam General Statistics Office</td>
</tr>
<tr>
<td>VHLSS</td>
<td>Vietnam Household Living Standard Survey</td>
</tr>
<tr>
<td>VND</td>
<td>Vietnamese Dong (Vietnamese Currency)</td>
</tr>
<tr>
<td>VRS</td>
<td>Variable Returns to Scale</td>
</tr>
<tr>
<td>SE</td>
<td>Scale Efficiency</td>
</tr>
<tr>
<td>SFA</td>
<td>Stochastic Frontier Approach</td>
</tr>
</tbody>
</table>
Chapter 1 INTRODUCTION

1.1 Introduction

Vietnamese agriculture is dominated by small-scale farm households. According to the Vietnamese General Statistics Office, the Vietnamese population grew from 84.1 million in 2006 to 87.8 million in 2011 (VGSO, 2007a; 2012). As the population increases, farm households must produce even more food to feed the growing population. Constraints to achieving food security in Vietnam include the small size and fragmentation of land holdings, especially in Northern Vietnam. Given fixed or falling supplies of agricultural land and labour, economic growth depends on improved efficiencies. It is important to measure the level and determinants of technical efficiency as part of a strategy to increase agricultural production.

Since the beginning of its ‘Doi moi’ market reform process in 1981, Vietnam has achieved remarkable success in increasing agricultural output, especially rice (Kompas, 2004 and Kompas et al., 2012). The importance of rice production in the Vietnamese economy demonstrates the importance of the efficiency of rice production and understanding the determinants of efficient production. Although rice production dominates the farming system in farm households, however, several other annual crops are grown in conjunction with rice to meet subsistence and cash needs.
The diversified cropping system is common in northern Vietnamese agriculture. Farms have been transformed since independence, from self-sufficient systems that produced mainly rice, to diversified farming systems, which now produce and market a large variety of products. Pederson and Annou (1999) claimed that crop diversification away from rice was associated with small farms in irrigated areas like the North. Minot et al. (2006) also revealed:

“Farm households in the poor area have been moving toward rice self-sufficiency on the basis of higher yields, while allocating any new land to higher-value crops, thus they have not been sacrificing rice production to diversify into higher-value crops” (Minot et al., 2006, p. 41).

Henin (2002) found farmers in the northern uplands adopting modern rice varieties and fertilisers (though they continue to use local varieties as well) and expanded production of cash crops.

This thesis identifies the technical efficiency of rice-based diversified farms and investigates its determinants in the Northern region of Vietnam using data from the Vietnam Household Living Standards Survey of 2008 (VHLSS 2008). The thesis applies two steps to examine the determinants impacting on technical efficiency. First, Data Envelopment Analysis is used to estimate technical efficiency and its components. Second, Tobit models are applied to explore the determinants of technical efficiency. This chapter presents the background and justification to the research in section 1.2. Section 1.3 presents the aims and objectives of the thesis. In section 1.4 the structure of the thesis is given.
1.2 Background to the study

Figure 1.1: Map of Vietnamese regions
Figure 1.1 shows the regions of Vietnam. The Red River Delta is the most important agricultural region of the North and the Mekong River Delta is the dominant agricultural region of the South. Northern agriculture is not considered as developed as the South. For example, as Minot et al. (2006) note that farm households in the southern regions have marketed output shares that are higher than those of households in the Red River Delta in the North while the northern uplands including North East and North West are the poorest area of the whole country with underdeveloped infrastructure. Although land in the northern uplands is not as limited as in the Red River Delta, almost half of the total land area is classified as non-arable (Minot et al., 2006).

Farm households in the northern part of Vietnam are made up of small and fragmented landholdings. Landholdings in Northern Vietnam are highly fragmented as a result of a land allocation policy that equitably distributes land, accounting for varying land quality (Pham et al., 2007). In the upland area of Northern Vietnam, poor land quality is exacerbated by geographic conditions (Pham et al., 2004). There was less concern with equitable distribution in the South, and land allocation to households in the South was also more likely to be based on landholding status prior to reunification in 1975. Therefore, in the southern region of Vietnam, the degree of land fragmentation is not so pronounced (Marsh et al., 2006). For example, in the South, households hold on average 1.5 plots of annual crop land, with the median equal to 1, by contrast, in the North, the mean is respectively 4.4, 5.2 and 5.1 plots per household in the Red River Delta, North East and North West, and the median is equal to 4 (See Table 1.1).
### Table 1.1: Fragmentation of landholdings: average number of plots per household

<table>
<thead>
<tr>
<th>Regions</th>
<th>Agricultural land</th>
<th>Annual crop land</th>
<th>Perennial crop land</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>The North</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red River Delta</td>
<td>4.9</td>
<td>4</td>
<td>4.4</td>
</tr>
<tr>
<td>(2.7)</td>
<td></td>
<td></td>
<td>(2.6)</td>
</tr>
<tr>
<td>North East</td>
<td>6.28</td>
<td>5</td>
<td>5.2</td>
</tr>
<tr>
<td>(3.9)</td>
<td></td>
<td></td>
<td>(3.7)</td>
</tr>
<tr>
<td>North West</td>
<td>6.4</td>
<td>5</td>
<td>5.1</td>
</tr>
<tr>
<td>(4.2)</td>
<td></td>
<td></td>
<td>(3.7)</td>
</tr>
<tr>
<td><strong>The Central Coast</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Central Coast</td>
<td>5.0</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td>(3.0)</td>
<td></td>
<td></td>
<td>(2.7)</td>
</tr>
<tr>
<td>South Central Coast</td>
<td>4.5</td>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>(13.1)</td>
<td></td>
<td></td>
<td>(11.9)</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>3.1</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>(2.0)</td>
<td></td>
<td></td>
<td>(1.8)</td>
</tr>
<tr>
<td><strong>The South</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South East</td>
<td>2.0</td>
<td>2</td>
<td>1.6</td>
</tr>
<tr>
<td>(1.3)</td>
<td></td>
<td></td>
<td>(1.2)</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>2</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>(1.5)</td>
<td></td>
<td></td>
<td>(1.4)</td>
</tr>
<tr>
<td><strong>Whole Country</strong></td>
<td>4.3</td>
<td>3</td>
<td>3.8</td>
</tr>
<tr>
<td>(4.8)</td>
<td></td>
<td></td>
<td>(4.6)</td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2004 (Brand, 2005)

Figures in parentheses are standard errors

Table 1.2 shows the number and structure of households using annual crop land by size. For example, 65 per cent of households with under 0.2 hectares of annual crops are in the North compared to 28 per cent in the Central Coast and 7 per cent in the South. Between 0.2 hectares and under 0.5 hectares, there are 49 per cent in the North, 35 per cent in the Central Coast and Highlands and 16 per cent in the South (VGSO, 2007b).
### Table 1.2: Number of households using crop land by size

<table>
<thead>
<tr>
<th>Regions</th>
<th>Total</th>
<th>%</th>
<th>Under 0.2 hectares</th>
<th>%</th>
<th>Between 0.2 hectares to 0.5 hectares</th>
<th>%</th>
<th>Between 0.5 hectares to under 2 hectares</th>
<th>%</th>
<th>2 hectares and over</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>The North</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red River Delta</td>
<td>4,969,408</td>
<td>49</td>
<td>2,439,111</td>
<td>65</td>
<td>1,927,313</td>
<td>49</td>
<td>533,882</td>
<td>25</td>
<td>69,102</td>
<td>17</td>
</tr>
<tr>
<td>North East</td>
<td>2,950,737</td>
<td>58</td>
<td>1,751,540</td>
<td>60</td>
<td>1,128,897</td>
<td>40</td>
<td>279,714</td>
<td>13</td>
<td>1,150</td>
<td>22</td>
</tr>
<tr>
<td>North West</td>
<td>1,587,401</td>
<td>32</td>
<td>620,009</td>
<td>40</td>
<td>675,711</td>
<td>42</td>
<td>279,714</td>
<td>17</td>
<td>11,967</td>
<td>23</td>
</tr>
<tr>
<td>The Central Coast</td>
<td>3,186,625</td>
<td>31</td>
<td>1,059,196</td>
<td>33</td>
<td>1,400,068</td>
<td>44</td>
<td>636,963</td>
<td>30</td>
<td>90,398</td>
<td>22</td>
</tr>
<tr>
<td>North Central Coast</td>
<td>1,731,317</td>
<td>53</td>
<td>600,397</td>
<td>35</td>
<td>858,987</td>
<td>52</td>
<td>257,780</td>
<td>14</td>
<td>14,153</td>
<td>11</td>
</tr>
<tr>
<td>South Central Coast</td>
<td>929,942</td>
<td>32</td>
<td>360,063</td>
<td>39</td>
<td>408,630</td>
<td>42</td>
<td>145,681</td>
<td>16</td>
<td>15,568</td>
<td>11</td>
</tr>
<tr>
<td>The South</td>
<td>2,089,047</td>
<td>20</td>
<td>259,782</td>
<td>12</td>
<td>641,494</td>
<td>31</td>
<td>938,335</td>
<td>45</td>
<td>249,436</td>
<td>61</td>
</tr>
<tr>
<td>South East</td>
<td>471,919</td>
<td>20</td>
<td>88,203</td>
<td>18</td>
<td>154,115</td>
<td>32</td>
<td>191,233</td>
<td>40</td>
<td>38,368</td>
<td>11</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>1,617,128</td>
<td>32</td>
<td>171,579</td>
<td>10</td>
<td>487,379</td>
<td>30</td>
<td>747,102</td>
<td>46</td>
<td>211,068</td>
<td>13</td>
</tr>
<tr>
<td>Whole Country</td>
<td>10,245,080</td>
<td>100</td>
<td>3,758,089</td>
<td>100</td>
<td>3,968,875</td>
<td>100</td>
<td>2,109,180</td>
<td>100</td>
<td>408,936</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Vietnam General Statistics Office 2007b

Farm sizes vary between regions. As Table 1.3 shows, the average size of farms in the Mekong River Delta of the South is about 1.2 hectares. The average landholding per farm household in the densely populated Red River Delta is less than one fifth of that in the Mekong River Delta. The average landholding in the North East is 0.43 hectares and in the North West, about 1.04 hectares. The average land area is 0.37 hectares per farm household in the North while it is 1.27 hectares per household in the South. Table 1.3 indicates small annual crop lands in the northern region of Vietnam, especially in the Red River Delta and North East. These show that Northern Vietnam is a case of land-scarce economy. In order to examine in more detail the efficiency of farm households run under this type of economy, this thesis focuses on farm households in the Red River Delta and the North East.
Table 1-3: Average annual crop land per households

<table>
<thead>
<tr>
<th>Regions</th>
<th>Number of household</th>
<th>Annual land area (hectares)</th>
<th>Average land area (hectares/household)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The North</td>
<td>4,969,408</td>
<td>1,820,460</td>
<td>0.37</td>
</tr>
<tr>
<td>Red River Delta</td>
<td>2,950,737</td>
<td>684,030</td>
<td>0.23</td>
</tr>
<tr>
<td>North East</td>
<td>1,587,401</td>
<td>686,090</td>
<td>0.43</td>
</tr>
<tr>
<td>North West</td>
<td>431,270</td>
<td>450,340</td>
<td>1.04</td>
</tr>
<tr>
<td>The Central Coast</td>
<td>3,186,625</td>
<td>1,865,310</td>
<td>0.58</td>
</tr>
<tr>
<td>North Central Coast</td>
<td>1,731,317</td>
<td>643,630</td>
<td>0.37</td>
</tr>
<tr>
<td>South Central Coast</td>
<td>929,942</td>
<td>464,780</td>
<td>0.49</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>525,366</td>
<td>756,900</td>
<td>1.44</td>
</tr>
<tr>
<td>The South</td>
<td>208,9047</td>
<td>2,662,390</td>
<td>1.27</td>
</tr>
<tr>
<td>South East</td>
<td>471,919</td>
<td>630,540</td>
<td>1.33</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>1,617,128</td>
<td>2,031,850</td>
<td>1.26</td>
</tr>
<tr>
<td><strong>Whole Country</strong></td>
<td><strong>10,245,080</strong></td>
<td><strong>6,348,160</strong></td>
<td><strong>0.62</strong></td>
</tr>
</tbody>
</table>

Source: Based on VGSO 2007b

These small and fragmented farm plots are a continuing problem. For example, it is difficult for farm households to transfer land-use rights in excess of government land limits (Marsh et al., 2006). Another reason is the failure of land markets to operate effectively because of government regulation of land transactions (Marsh et al., 2006; Vasavakul, 2006).

There are empirical findings implying the importance of crop diversification in the North. Minot et al., (2006) also found that crop diversification contributed to the raising of living standards in the northern uplands, especially for poor households. Kompas (2004) argued that although rice is an important crop in Vietnam, it should not be grown intensively in every province in Vietnam, especially in the North. Low tractor use due to small farm size and the slow development of rural
credit markets for capital and land in the North were seen to restrict the level and growth of efficiency substantially. According to Pham et al. (2004), land fragmentation was positively related to crop diversity in some provinces of the North. They claimed that in some areas, a degree of land fragmentation may be beneficial by cultivating plots in different geographical areas, variation in output may help to reduce the risks caused by drought, flood and diseases. Another advantage is that farmers may be able to use their labour more effectively across seasons. In peak times such as transplanting and harvesting periods, more labour is demanded, and even child labour is very common in these periods, thus farmers may reduce peak times by diversifying crops in different plots. This analysis also showed that increasing plots per farm was associated with higher net values of farm production.

Rice is the most important crop in Vietnamese agriculture and it plays a central role in the economy. It is planted on about 65.1 per cent of the land area for annual crops and 43.7 per cent of total agricultural land (VGSO, 2007b) and produced in all of the 64 provinces in Vietnam. Rice is not only the second-largest foreign exchange earner of the country but it also accounts for nearly 90 per cent of the output of food grains (Kompas et al., 2012). The importance of rice production in the Vietnamese economy demonstrates the importance of the efficiency of rice farms. However, there is empirical evidence that rice farms in all regions are operating at an inefficient point (Vu, 2008; Huynh and Yabe, 2011). In Northern Vietnam, rice is cultivated on 63.1 per cent and other crops on 36.9 per cent of the land area for annual crops (VGSO, 2007b). Therefore, this thesis focuses on rice-based diversified crops to better understand technical efficiency of farms.
Northern Vietnamese agriculture has characteristics that can impact on farm production. These characteristics include farm size, level of land fragmentation and crop diversification that development planners, policy makers and researchers need to better understand. There is no research examining the determinants of technical efficiency in the North. Although the Vietnamese government granted land-use rights to support plot consolidation and land accumulation, the identification of whether farm size, land fragmentation and crop diversification are important determinants of technical efficiency is essential to an understanding of the implications for policy.

The aim of this thesis is to identify the determinants of technical efficiency of annual cropping in the northern part of Vietnam. Farrell’s (1957) paper has led to many applications of efficiency measures to evaluate the performance of decision-making units such as farm households. Many such studies have shown substantial inefficiency and identified the potential to improve the productivity of agricultural production in developing agriculture. However, Vietnamese agriculture has not received much attention in the research literature, particularly on the impact of crop diversification and land fragmentation on technical efficiency of farms. Therefore, a study of a technical efficiency in Vietnamese agriculture would seem logical as a means of uncovering the factors that hinder productivity growth of annual cropping.

The impact of crop diversification on technical efficiency should inform the Government’s diversification policy for Vietnamese agriculture, especially for diversification from the base of
rice production. The thesis also examines the impact of land fragmentation and farm size on the efficiency of farms to better understand the behaviour of farmers using land for annual crops.

For developing countries, Schultz (1964) posited the theory that small farms use factors of production more efficiently than large farms. This thesis tests to find out whether there is an inverse relationship between farm size and technical efficiency in the case of the northern part of Vietnam. In revising the *Vietnamese Land Law* in 1998 (Circular No. 346/1998/TT-TCDC, 1998), the Vietnamese government supported farm and plot consolidation by outlining procedures and designing responsibilities for land transactions to encourage efficient land use in areas like the North. This thesis thus focuses on farm households in the North to examine whether the inverse relation between farm size and technical efficiency can exist in a land-scarce region to assess the present land policy.

1.3 Purposes of research and research questions

The thesis identifies the determinants of technical efficiency of farms and the main research question that is addressed is: *What are the determinants of technical efficiency of annual cropping on farms in the Northern region of Vietnam?*
Farm size, land fragmentation and crop diversification are the three main concerns in this thesis. (Some other possible determinants are also examined where relevant). The research questions are:

- What are the levels of technical efficiency and its components of annual cropping for farm households in the northern region of Vietnam? (Are there total technical, pure technical or scale inefficiencies?)
- Are farm size, land fragmentation, crop diversification, land use intensity, family labour, land to family labour ratio, education and age of farm head and off-farm income ratio determinants of technical efficiency?

A main objective of this study is to help policy makers better understand the factors that can influence efficiency differentials among farms by determining the relationship between technical efficiency and farm size, land fragmentation, level of crop diversification and other determinants such as land use intensity, family labour, land to family labour ratio, age and education of farm head and off-farm income ratio of annual cropping in the case of Northern Vietnam.

This thesis is important because, firstly, the identification of determinants impacting on technical efficiency of farms is a significant step to helping agricultural growth through productive agricultural strategy. Secondly, the main consequence of technical inefficiency is to raise production costs, therefore the determinants of technical efficiency of farms may be used to assist farmers to improve their productivity.
1.4 Structure of the thesis

The chapters in this thesis are organized as follows. Following this introductory chapter,

**Chapter 2** provides an overview of definition of technical efficiency from the academic literature and explains the measurement of technical efficiency, and reviews significant determining factors in the literature relating to technical efficiency.

**Chapter 3** presents the thesis hypotheses with regard to the literature of determinants of technical efficiency of farm households.

**Chapter 4** outlines and justifies the methodology used in this thesis including method of Data Envelopment Analysis to examine technical efficiency and Tobit models to explore the determinants.

**Chapter 5** presents and reviews the data related to the thesis and presents the empirical findings in the context of the hypotheses in Chapter 3. **Finally,**

**Chapter 6** provides a conclusion to the thesis, which includes implications for Vietnamese agrarian policy, contributions, limitations of the study and suggestion for further research.
Chapter 2  LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to examine past research that has been conducted into factors related to farm efficiency. The chapter is organized in several sections. In section 2.2, a definition of technical efficiency is given and the major research literature findings on farm efficiency are reviewed in some details. Section 2.3 presents the determinants of technical efficiency identified in the light of the literature. Choice of determinants of technical efficiency is based on the existing literature on rice-based cropping and the justification for their inclusion is discussed in section 2.4. Finally, section 2.5 presents an assessment of the literature.

2.2 Efficiency of farms

2.2.1 Definition of efficiency

The terms productivity and efficiency are often used interchangeably but they are not precisely the same things. Productivity, including partial factor productivity and total factor productivity, is an absolute concept and is measured by the ratio of outputs to inputs. Efficiency is a relative concept and is measured by comparing the actual ratio of outputs to inputs with the optimal ratio of outputs to inputs. The recent history of efficiency measurement begins with Farrell (1957) who defined a measure of firm efficiency. The efficiency of a firm is defined as the actual
productivity of a firm relative to maximal potential productivity. This measures the firm’s success in producing as much as output as possible from a given set of inputs.

Farrell (1957) proposed that the economic efficiency of a firm or a farm consists of two components. Technical efficiency measures the ability of a farm to obtain maximal output from a given set of inputs (output-oriented measures); or use the minimum feasible amount of inputs to produce a given level of output (input-oriented measures). Allocative efficiency measures the ability of a farm to use inputs in optimal proportions given their respective prices and the production technology. Allocative inefficiency arises when inputs of production are used in a proportion that does not minimise the costs of producing a given level of output. Economic efficiency is the product of technical efficiency and allocative efficiency. A firm that is both technically and allocatively efficient is said to be an economically efficient firm.

2.2.2 Technical and allocative efficiency measurement

The efficiency of a firm, or the maximal potential productivity, is defined by the production frontier. Measurement of efficiency involves measurement of the distance from observed data point to that frontier (Coelli et al., 2005).

The original frontier function model introduced by Farrell (1957) uses the efficient farm isoquant to measure economic efficiency (EE), and to decompose this measure into technical efficiency
(TE) and allocative efficiency (AE). In the Farell framework, economic efficiency is a measure of overall performance and is equal to

\[ EE = TE \times AE. \]

The technical and allocative efficiency are graphically demonstrated in Figure 2.2 below. This is used to illustrate the concept of input-oriented measures. It is assumed that a set of farms use two inputs \( x_1 \) and \( x_2 \) to produce output \( y \), under the assumption of constant returns to scale.

**Figure 2.1: Technical and Allocative Efficiencies (Coelli et al., 2005)**

Point P is a technically inefficient farm.

Q = a technically efficient farm (any point on SS’)

Q’ = an allocatively efficient farm (Slope = ratio of price of \( x_1 \) and \( x_2 \))

AA’ = the isocost line

SS’ = the isoquant of efficiency
The unit isoquant of technically efficient input combinations is represented by SS’ and permits the measurement of technical efficiency. Where the farm uses quantities of inputs defined by, for example, point P technical inefficiency can be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction of the output level. Technical efficiency is expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs need to be reduced to achieve technically efficient production. Technical efficiency is commonly measured by the ratio OQ/OP which is equal one minus QP/OP.

Technical Efficiency:

\[ TE = \frac{OQ}{OP} = 1 - \frac{QP}{OP} \]

AA’ is known as the input price ratio, represented by the slope of the isocost line. The allocative efficiency (AE) of the farm operating at P is defined to be the ratio OR/OQ since the distance RQ represents the reduction in production cost that would arise if production were to occur using the allocative (and technically) efficiency input proportion at point Q’, instead of the allocatively inefficient input proportion at point P.

Allocative Efficiency:

\[ AE = \frac{OR}{OQ} \]

The total economic efficiency is defined to be the ratio OR/OP where the distance RP can also be interpreted in terms of cost reduction. We can show that the product of technical and allocative efficiency measures provides the measure of overall economic efficiency.

Economic Efficiency:
EE = OQ/OP = (OQ/OP) x (OR/OQ) = TE x AE

**Scale efficiency**

Technical efficiency (Total technical efficiency) consists of pure technical efficiency and scale efficiency where there are variable economies of scale. It is possible that a firm is both pure technically and allocatively efficient but the scale of operation of the firm may not be optimal (Coelli et al., 2005). If a firm is too small in its scale of operation, it may fall within the increasing returns to scale. A firm may be too large and it may be operate within decreasing returns to scale. In both of these cases, the firm is using a variable returns to scale (VRS) technology and efficiency of the firm might be improved by changing their scale of operations. If the underlying production technology is a constant returns to scale (CRS) technology then the firm is automatically scale efficient.

A one-input (x), one-output (y) VRS production technology is depicted in Figure 2.3. The firms operating at points A, B, C are all VRS technically efficient (or pure technically efficient), because they are operating on the VRS production frontier (SS'). However, because the productivity of each of these firms is equal to the ratio of their observed output and input quantities (y/x), we can see that even though these three firms are all technically efficient (pure technically efficient), they are not equally productive. This apparent inconsistency is due to the effects of scale.

Point B is operating at the most productive scale (where SS' is tangential to a ray from the origin, this ray is called the CRS frontier).
Point A is operating in the increasing returns to scale portion of the production frontier. It could become more productive by increasing its scale of operation towards point B.

Point C is operating in the deceasing returns to scale portion of the production frontier. It could become more productive by decreasing its scale of operation towards point B.

A scale efficiency measure can be used to indicate the amount by which productivity can be increased by moving to the point of the most productive, point B. Here, point D is depicted as a technically inefficient firm. The productivity of firm D (as reflected in the slope of the ray from the origin) could be improved by moving from point D to point A on the VRS production frontier SS’ (same output for fewer inputs). Productivity could be further improved by moving from the point A to the point B which represents scale efficiency.
The ratio of the slope of the ray OD to the slope of the ray OA is equal to the ratio \( GA/GD \). The ratio of the slope of the ray OA to the slope of the ray OF (which also equals the slope of the ray OB) is equal to the ratio \( GF/GA \). Thus we can clearly use distance measures to calculate the productivity differences.

The pure technical efficiency of firm at D is measured relative to the distance from point D to the VRS technology (VRS production frontier) at A and is equal to the ratio

\[
\text{TE}_{\text{VRS}} = \frac{GA}{GD} \text{ (pure TE)}
\]

The scale efficiency (SE) of firm at D is measured relative to the distance from the VRS technically efficient point, A, to the CRS technology (CRS frontier) and is equal to the ratio

\[
\text{SE} = \frac{GF}{GA}
\]

The distance from the observed point D to the CRS technology is called CRS technical efficiency score (\( \text{TE}_{\text{CRS}} \) or total technical efficiency)

\[
\text{TE}_{\text{CRS}} = \frac{GF}{GD} \text{ (Total TE)}
\]

It can then be used to calculate the SE of firm at D as

\[
\text{SE} = \frac{\text{TE}_{\text{CRS}}}{\text{TE}_{\text{VRS}}} = \frac{(GF/GD)}{(GA/GD)} = \frac{GF}{GA}
\]

Efficiency is an important economic concept for the measurement of economic performance of a production unit. As seen in the above definition, production efficiency is concerned with the
relative performance of the process used in transforming inputs into outputs. Battese (1992); Bravo-Ureta et al., (1993) and Bravo-Ureta et al. (2007) reviewed the concepts, models and measurement of technical efficiency and production frontier technology stimulated by Farrell (1957). They identified the importance of an economic concept of farm efficiency and the use of frontier production models to compare the efficiency of farms. In this light, this thesis applies a frontier production approach (best practice frontier) to explore the technical efficiency of farm households. Due to limited data, the thesis focuses on estimating technical efficiency rather than allocative and economic efficiency. The best practice frontier approach will be presented in detail in section 2.3.3

2.2.3 Approaches to measuring efficiency

There are two main advantages of using frontier functions models to measure efficiency of farms (Coelli, 1995). First, it is influenced by the best performing farms and hence reflects the technology farms are using. Second, the frontier function models represent a best-practice technology against which the efficiency of farms can be measured.

The large number of frontier models that have been developed based on Farrell’s work can be classified under two basic types: parametric and non-parametric. Parametric frontiers rely on a specific functional form while non-parametric frontiers do not. Non-parametric models, usually known as data envelopment analysis (DEA) models, are based on mathematical programming techniques. DEA is a linear programming technique, which uses data on inputs and outputs to
construct a best practice production frontier over the data points. The frontier surface is constructed by the solution of a sequence of linear programming problems (one for each firm in the sample). The efficiency of a firm is measured relative to the efficiency of all the other firms subject to the restriction that all firms are on or below the frontier. The focus is not on the estimation of an average technology production function used by all units analyzed, but to identify the best practice farms. The best-practice production frontier is constructed and all farms in the analysis are related to this frontier. Data envelopment analysis is based on the concept that a farm that employs less input than another to produce the same amount of output can be considered as more efficient. The efficiency frontier is constructed of linear segments that join up those observations with the highest ratio of output to input. The resulting frontier thus envelops all the other observations (Coelli et al., 2005).

Another important distinction is between deterministic and stochastic frontiers. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise (Bravo-Ureta et al., 1993). Broadly, two sets of approaches to the measurement of agricultural production efficiency, known as stochastic frontier approach (SFA) and data envelopment analysis (DEA) are compared in Table 2.1.

Both approaches, SFA and DEA, have their own strengths and weaknesses. The SFA method provides a basis for hypothesis testing but it is more prone to misspecification error. The DEA approach as a deterministic method takes no account of the possible influence of measurement error and other noise in the data. On the other hand, it has the advantage of removing the
necessity to make arbitrary assumptions regarding the functional form of the frontier such as cost function, profit function and the distributional form of the errors (Coelli, 1995).

### Table 2.1: Comparing methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stochastic frontier approach (SFA)</strong></td>
<td>Incorporation of stochastic error</td>
<td>The imposition of an explicit functional form and distribution assumption of the error term</td>
</tr>
<tr>
<td><strong>Data envelopment Analysis (DEA)</strong></td>
<td>Less sensitive to model misspecification</td>
<td>Sensitive to measurement errors and data noises</td>
</tr>
</tbody>
</table>

Source: Coelli, 1995

### 2.2.4 Technical efficiency of farms in developing countries

Farrell’s (1957) paper has led to many studies of efficiency measures to evaluate the performance of farms. Most studies of efficiency measures have focused on the estimation and explanation of agricultural efficiency in developing countries. These studies identify the potential to improve the efficiency of agricultural production. Most of these studies were carried out to estimate technical efficiency and only a few studies looked at both technical and allocative efficiency of farms (Bravo-Ureta and Pinheiro, 1993; Javed, 2009).
DEA is an accepted tool in economic analysis used in many empirical studies of efficiency (Hartwich and Kyi, 1999). It seems that from 1990s to the present, studies with a DEA approach have become more prevalent. In particular, DEA is used broadly to measure technical efficiency, as well as allocative efficiency and scale efficiency.

In comparing the models used to measure production efficiency in six Central and East European countries, Gorton and Davidova (2004) stated that the advantage of DEA in comparison to the parametric approach is that it can handle multiple-output and multiple-input situations simultaneously, as well as cases where inputs and outputs are quantified using different units of measurement. In fact, within the DEA approach, multiple inputs and multiple outputs are reduced to a single virtual input and virtual output and finally to a single summary relative efficiency score. DEA calculations are designed to maximise the relative efficiency score of each unit, subject to the condition that the set of weights for each unit must be feasible for all the other units included in the calculation. DEA involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data. Efficiency measures are then calculated relative to this surface. This thesis uses multi output and input data, therefore DEA is more appropriate than SFA.

DEA accounts for the measurement of various kinds of farm efficiencies (including AE and SE). Haji (2006) argued that DEA has provided new insights and additional information not available from conventional econometric methods with the benefits of computation, dual variables and clear interpretations. He stated that the weakness of econometric methods is that, a regression
approach relies on a parametric specification of the production function such as cost function or profit function. For example, the profit function specification proposed by many researchers provides a consistent framework for investigating econometrically the technical, allocative and scale efficiency of farms but this framework relies on a fairly restrictive Cobb-Douglas technology, which implies unitary elasticity of substitution among inputs (Chavas and Aliber, 1993). This assumption is not applicable to the farms studied in this thesis. In the review of choice parametric models, Bravo-Ureta and Pinheiro (1993) identified a high degree of sensitivity of the efficiency measures to the choice of functional forms and the distributional assumptions. The applied DEA approach is more appropriate to analysing production processes in developing countries where knowledge about underlying production technologies is weak (Kalirajan and Shand, 1999; Brázdík, 2006). The DEA approach used in this thesis avoids the specification bias from a choice of functional forms and distributional assumptions.

The trade-offs between SFA and DEA approaches suggest the choice among models depends upon the objective of the research, the type of data and the choice of functional forms considered to represent the production technology. According to the literature on SFA and DEA methods, comparison has shown mixed results. Headey et al. (2010) argued that SFA is preferable to DEA for estimating total factor productivity growth rate when there was a relatively high degree of noise and measurement error in the input and output data. Hjalmarsson et al. (1996) reported both similar and dissimilar results obtained from the SFA and DEA depending on the inclusion of the control variables in the SFA and sequential specification in the DEA. Sharma et al. (1997) reported a greater mean technical efficiency obtained from SFA than those estimated from DEA (both CRS DEA and VRS DEA). In contrast, Wadud and White (2000) and Vu (2008) showed
the efficiency measure on rice production from the VRS DEA was greater than that estimated from SFA. They also found Spearman correlation coefficients between the technical efficiency rankings obtained from SFA and DEA are highly positively correlated, implying that the technical efficiency scores of rice farms are consistent in both methods. Thiam et al. (2001) conducted a meta-analysis on the sensitivity of efficiency estimates to the choice of the methodology in the developing countries’ agriculture using 32 technical efficiency studies. Their results indicate that the estimates from these studies are independent of the methodology employed. These results broadly support the use of DEA to estimate technical efficiency.

The Data Envelopment Analysis research approach used in this thesis is similar to research estimating technical efficiency and its components in the literature. The method in detail will be presented in section 4.4.1 of Chapter 4.

2.2.5 Inverse relationship between efficiency and farm size in farms

Schultz (1964) proposed the “inverse relationship” theory that is known as “poor but efficient”. According to Schultz (1964), small farmers in developing countries use factors of production more efficiently than large farmers. Much evidence across different countries seems to identify an inverse relationship between farm size and yields per unit area.
Since Sen (1962) observed an inverse relationship between farm size and yields from an analysis of Indian farm management, there has been much debate on this topic and its relevance to the design of rural development strategies. Many studies have found a significant inverse relationship and supported redistributive land reform on economic grounds because a decrease in average farm size would increase output from the sector. These included Berry and Cline (1979) for Brazil, Colombia, Philippines, Pakistan, India and Malaysia; Cater (1984) for Haryana in North India; Heltberg (1998) for Pakistan, Chand et al. (2011) for India. Chand et al. (2011) claimed that because the concentration of smallholders is very high in Asia, it is imperative to look for ways and means to improve productivity of smallholders rather than worrying about the size of landholdings. His results supported reducing land inequality and lowering agricultural land ceiling limits to improve productivity and growth of Indian agriculture.

In a comprehensive review of the literature, Dyer (1997) has identified explanations for the inverse relationship. First, smaller farms are located on land of better quality. Second, farms become more complex organisations as they become larger, and are thus subject to managerial diseconomies of scale. Smaller farms do not face this constraint, and are thus, on a per unit basis, more productive. Third, small farms have a greater knowledge of local agro-ecological conditions, which can permit greater intensity of land usage as well as a more optimal choice of crop mix. Fourth, as farms increase in size and become more complex organizations; they have to manage wage labour. Fifth, smaller farms use more labour per unit of land than do larger farms, and this greater labour intensity explains why smaller farms produce greater yields per unit of land.
Dyer (1997) argued that the inverse relationship is neither a product of superior efficiency on small farms nor is it due to better quality land on the small farms but arises from the desperate struggle of poor farmers for survival on below subsistence plots of land. Thus, according to Dyer (1997) to understand the inverse relationship it is necessary to place it within a more dynamic process in which the emergence of differentiated access to the forces of production is a result of stratified access to the means of production. This leads to farm class differentiation among farm households. According to Dyer (1997), with farm class differentiation, exploitative relationships that develop between rural dominant classes and smaller poor farms and marginal farms, force factor intensification upon poor farms and this, in turn, results in higher cropping intensities, higher labour inputs per hectare and higher yields.

Niroula and Thapa (2005) argued that the theory of inverse relationship between farm size and productivity held little value when the impact of land fragmentation was considered. According to Niroula and Thapa (2005), when farm plots are fragmented, the increased cost of use not only undermines operational efficiency, but also leads to unsuitable land use because farmers are compelled to adopt selective and extractive strategies. For example, land fragmentation produces a farm structure that prevents application of labour and fertiliser and discourages use of land for locationally suitable cropping systems, thereby undermining efficient use of land. Dispersion of land parcels can contribute to depletion of soil fertility as well as weakening economic competitiveness of farmers through increasing cost of labour and other inputs (Paudel, 2001).
Niroula and Thapa (2005) claimed that the inverse relationship between landholdings and productivity may be only relevant in the subsistence economy, where there is no competition between farmers with varying landholding size and farms rely on local inputs, including seed and fertilizer, and there are few alternative employment opportunities outside agriculture.

The Green Revolution may have diminished or reversed the inverse relationship by development of technology that is advantageous for larger-scale, proto-capitalism farms. The advantages of smaller, more marginal farms may be more than offset by the technological edge accorded to larger-scale farms that adopt the new technique (Heltberg, 1998).

Binswanger et al. (1993) have indicated that most of the empirical work on the farm size-productivity relationship has been flawed by methodological shortcomings, and has failed to deal adequately with the complexity of issues. This thesis addresses this criticism by focusing on efficiency rather than yields.

Given the importance of the inverse relationship between farm size and productivity to land policy and market policy in developing countries, many studies investigate not only the relationship between farm size and yields per unit of land but also the relationship between farm size and technical efficiency. Battese (1992); Gorton and Davidova (2004) reviewed many papers on technical efficiency and suggested the importance of researching technical efficiency. The inverse relationship between yields and farm size, although valid for traditional agriculture
with low level of technology, cannot be assumed to exist in an agriculture experiencing technical change (Deolalikar, 1981). The studies which utilize technical efficiency to predict impact of farm size will be discussed in detail in section 2.4.1.

### 2.3 Research studies of determinants of technical efficiency

Understanding why farms differ in their relative efficiency has been seen as crucial to several debates concerning likely future structural change, supply response, the size of the agricultural labour force and international competitiveness (Gorton and Davidova, 2004).

#### 2.3.1 Farm size

Most studies of agricultural productivity in developing countries support the theory developed in the paper by Schultz (1964) in which he argued that smaller farms were more productive because land was used more intensively or labor allocated more efficiently. However, the literature still contains varying findings about the relationship between farm size and efficiency. Much research has discovered an inverse relationship between farm size and the technical efficiency of farms, but Bagi (1982), Huang and Bagi (1984), Ray (1985) and Croppenstedt (2005) found that small and large farms were equally technically efficient. The relationship between farm size and efficiency was found to be non-linear with productivity first falling and then rising with size in the Brazilian Centre-West (Helfand and Levine, 2004). Table 2.2 summarises findings from the literature.
### Table 2.2: Examples of varying farm size-technical efficiency groups

<table>
<thead>
<tr>
<th>Findings</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small and large farms are equally efficient</strong></td>
<td></td>
</tr>
<tr>
<td>Crop farms in West Tennessee</td>
<td>Bagi (1982)</td>
</tr>
<tr>
<td>Farms in Punjab and Haryana India</td>
<td>Huang and Bagi (1984)</td>
</tr>
<tr>
<td>Farms in West Bengal India</td>
<td>Ray (1985)</td>
</tr>
<tr>
<td>Wheat Farms in Egypt</td>
<td>Croppenstedt (2005)</td>
</tr>
<tr>
<td><strong>Inverse relationship</strong></td>
<td></td>
</tr>
<tr>
<td>Maize and mixed farms in South African</td>
<td>Zyl et al. (1995)</td>
</tr>
<tr>
<td>Farms in Madagascar</td>
<td>Barrett (1996)</td>
</tr>
<tr>
<td>Farms in Pakistan</td>
<td>Barki and Shah (1998)</td>
</tr>
<tr>
<td>Farms in Honduras</td>
<td>Gilligan (1998)</td>
</tr>
<tr>
<td>Mixed farms in Kenya</td>
<td>Oduol et al. (2006)</td>
</tr>
<tr>
<td>Mixed vegetable farms in Ethiopia</td>
<td>Haji (2006)</td>
</tr>
<tr>
<td>Rice-Wheat farms in Pakistan</td>
<td>Javed et al. (2010)</td>
</tr>
<tr>
<td><strong>Lower technical efficiency in small farms</strong></td>
<td></td>
</tr>
<tr>
<td>Wheat farms in Punjab India</td>
<td>Jha et al. (2000)</td>
</tr>
<tr>
<td>Rice farms in Indonesia</td>
<td>Fabiosa et al. (2004)</td>
</tr>
<tr>
<td>Rice farms in West Java Indonesia</td>
<td>Brázdik (2006)</td>
</tr>
<tr>
<td><strong>Non-linear with productivity first falling and then rising with size</strong></td>
<td></td>
</tr>
<tr>
<td>Brazilian Center-West</td>
<td>Helfand and Levine (2004)</td>
</tr>
</tbody>
</table>
The literature has witnessed a wide concern about the relationship between farm size and productivity as well as efficiency because land reform and farm restructuring have brought about comprehensive, politically induced changes in the distribution of farm sizes. However, the farm size-efficiency debate on its own is too restrictive in a framework for studying variations in farm performance. Several authors have argued that differences in management input are more important than scale. This means efficiency is related to the influence of management rather than to the relationship between size and efficiency (Adesina and Djato; 1996; Hoque, 1988; Shively and Zelek, 2003). The literature implies that an appropriate investigation involves examining farm size and other variables.

Gorton and Davidova, (2004) revealed that the optimal farm size for a particular production system in a particular country will depend on a set of factors. They reviewed the studies that have attempted to understand variations in individual farm efficiency into two categories of factors: agency and structural factors. First, the most common agency factor investigated has been human capital such as the effects of education and training of farm header (Stefanou et al., 1988); experience in farming (Summer and Leiby, 1987). Regarding structural factors, these can be divided into on-farm and off-farm issues. The most prominent on-farm issue investigated has been agri-environmental conditions, including soil quality, altitude, climate, rainfall and access to water. Off-farm structural factors include institutional factors such as relationships and the nature of transaction costs between agents along the agricultural supply chain.
In sum, the literature reviewed in this thesis has presented the role of farm size in investigating technical efficiency; however it also indicates that technical efficiency might be better explained by incorporating other variables rather than farm size only. This thesis takes this approach by examining a range of determinants of efficiency.

2.3.2 Land fragmentation

Land fragmentation has both private and social costs and benefits. If it is seen that more labour and other resources are used than is necessary and these resources can be used more effectively elsewhere in the economy, then there is likely to be an overall economic gain from reduced fragmentation. Land fragmentation may have negative impacts on farms such as cost increases, higher labour use, less mechanisation and difficulties arising from application of new technology. On the other hand, there are conceptually reasons why it may be beneficial to farmers, such as risk management, seasonal labour use and crop diversification. Therefore, some farmers may wish to keep land fragmented (Bentley, 1987).

In Africa and Asia, labour is typically cheap and crop production is mainly carried out by hand cultivation and animal traction. In such cases, particularly on small scale and self-sufficient farms, fragmentation is common. Fragmentation is also commonly a result of geographical conditions where the terrain is hilly and upland areas exist. Historical and geographical causes of land fragmentation are hard to overcome and it may take a long time to consolidate such land areas. Land consolidation may benefit farmers in the short term through higher crop productivity,
but may result in cost increases through the loss of risk management strategies and other private benefits of having many plots (Blarel et al., 1992; Nguyen et al., 1996).

Various studies have examined land fragmentation in different countries and regions. The topics covered in these studies include explanations of land fragmentation, cost estimates of fragmentation, effects of land fragmentation on agricultural production. However, there are few studies examining the relationship between land fragmentation and technical efficiency. The identification of the effects of land fragmentation is complicated. Nguyen et al. (1996) found that fragmentation did have an economic cost in China. On other hand, in another empirical study in China, Tan et al. (2008) argued that changes in the number of plots and plot size distribution did not affect total production costs per unit of output, but caused a shift between cost categories. A higher degree of land fragmentation increased labour costs but reduced fertiliser, seed and oxen costs. This study showed that farmers with highly fragmented plots switch to more labour-intensive methods and use fewer modern technologies and the net impact on total production costs is insignificant.

Rahman and Rahman (2008) found that a one per cent increase in land fragmentation reduces technical efficiency in rice by 0.03 per cent in Bangladesh. Manjunatha et al. (2013) found that farms with fragmented land had significantly lower efficiency levels than their counterparts who operated in a single piece of land. In contrast, Niroula and Thapa (2007) examined the impacts of land fragmentation on input use, crop yield and efficiency in the mountains of Nepal and the analysis revealed that small parcels were more productive and had higher technical efficiency
than larger parcels. This observation is interesting as it implies that land fragmentation has a positive impact on production. This thesis examines land fragmentation as a determinant of technical efficiency.

2.3.3 Crop diversification

Crop diversification refers to growing many crops on a single farm. The switch from subsistence food production to commercial agriculture typically increases crop diversification (Minot et al., 2006; Ibrahim et al., 2009). Mixed diversified cropping can include cash crops, subsistence crops and alternative or non-traditional cash crops (Vedenov et al., 2007).

The choice of crops in diversification can depend on commercial choices of farm households. According to Pingali and Rosegrant (1995) food production systems can be characterised as subsistence, semi-commercial and commercial systems. As economies grow, households shift away from traditional self-sufficiency goals and towards profit and income-oriented decision making, so farm output is accordingly more responsive to market trends. In rice farming systems, increasing commercialisation leads to both a seasonal diversification out of rice monoculture systems by including non-rice crops in rotation with rice and introduction of specialised products.
Farmers grow different types of crops as a hedge against risks that could occur due to bad weather, crop disease and falling crop prices. However, growing an additional crop on a given plot of land requires knowledge of the soil type and its nutrients, knowledge of the level of inputs to be used and when the crop has to be planted and predictions about future markets. Crop diversification results in managerial complexity (Haji, 2006).

Diversified crop systems may maintain an ecosystem’s healthy functioning and enable it to absorb not only the shocks to the natural resource base but also those brought by sudden changes in the economic environment (Holling, 1995).

Smallholders have been most successful in increasing productivity when diversifying their activities through an adaptive growth strategy, entailing a combination of new cash cropping activities. Fleming and Hardaker (1994) observed that the main path to the development of smallholder farming systems has been through improved technologies, management practices and field husbandry methods that are simple and mostly inexpensive in cash terms. This path requires considerable ability to make efficient use of family labour and management resources particularly by crop diversification.

Studies examining the explicit relationship between crop diversification and technical efficiency at farm level are few, with mixed conclusions. For example, Coelli and Fleming (2004) and Rahman (2009) concluded that crop diversification significantly improves technical efficiency on
farms in Papua New Guinea and in Bangladesh, respectively, whereas Haji (2006) concluded that crop diversification significantly reduces allocative and economic efficiency in Ethiopian farms. Vedenov et al. (2007) found production of staple crop (corn) with either coffee or other cash crops results in increased efficiency as a result of the economies of diversification, while production of coffee with other cash crops leads to lower efficiency.

The impact of crop diversification should be determined by empirical studies. What is clear is that more evidence is required before firm conclusions can be drawn in the case of Vietnam. This thesis will contribute to this evidence by including measures of crop diversification as a determinant of technical efficiency.

2.3.4 Other factors

Aside from farm size, land fragmentation and crop diversification, there may be other factors that have influenced the efficiency in agricultural production. Although the literature has not reached any firm conclusions, a number of variables that appear to influence technical efficiency have been identified. Variables such as human capital (Stefanou and Saxena, 1988; Coelli and Battese, 1996; Dhungana et al., 2004; Rios and Shively, 2005), farmer’s risk attitude (Dhungana et al., 2004), access to institutions, credit, modern inputs (Adesina and Djato, 1996; Helfand and Levine, 2003; Rios and Shively, 2005), agri-environmental conditions including soil quality, climate, rainfall and access to water (Davidova et al., 2002) and resource ownership (Rahman
Analysing information about these variables may have policy implications for improved efficiency.

The most common factor investigated has been human capital, particularly experience and education of farmers. There are research studies implying that training of farm operators and age of farmers may have an effect on the level of efficiency (Stefanou and Saxena, 1988; Dhungana et al., 2004). Other researchers suggest that the level of education of the farmers is a significant influence upon efficiency (Coelli and Battese, 1996; Dhungana et al., 2004).

There is, however, conflicting evidence about the influence of education on farmers. Most studies argue that there would be more economically efficient farms with more educated farmers as a result of their better skill, access to information and good farm planning. For instance, Coelli and Battese, (1996), Dhungana, et al. (2004), Villano and Fleming (2006), Asadullah and Rahman (2009) demonstrated the significance of farmers’ education in raising farming technical efficiency in India, Nepal, Philippines and Bangladesh, respectively. On the other hand, Coelli et al. (2002) failed to identify a significant impact of education on technical efficiency in Bangladesh. Fleming and Lummani (2001) and Hasnah et al. (2004) reported a significantly negative impact of education on technical efficiency in Papua New Guinea and West Sumatra-Indonesia, respectively. Rios and Shively’s study of Vietnamese coffee farms also found that efficiency falls with higher levels of education on small farms because education increases opportunities for off-farm work and thereby reduces on-farm management intensity (Rios and Shively, 2005). What is clear is that more evidence is required before firm conclusions can be
drawn in the case of Vietnam about the impacts of education and off farm work. This thesis includes farm head’s age, education and off-farm work as determinants of technical efficiency.

The contrasting evidence provided by the empirical studies proves that individual economies within the developing countries are unlikely to demonstrate a uniform relationship between farm size, land fragmentation, crop diversification and other determinants of technical efficiency. Therefore, it is important to ascertain the impact of these determinants case by case. In the case of Vietnam it is rice which is the dominant crop. A more focused exploration on determinants of technical efficiency in the context of rice-based farming is given in section 2.4.

2.4 Context of rice-based farming

International and Vietnamese studies have identified a number of determinants of the technical efficiency of rice farms. They include farm size (which is based on land area and output value), land fragmentation and the characteristics of farms such as family labour size, off-farm income of farms, education, age, experience and other factors such as extension services, access to credit, environmental degradation, infrastructure and irrigation (Table 2.3).
Table 2.3: Review of technical efficiency of rice-based farming in developing countries

<table>
<thead>
<tr>
<th>Determinants of technical efficiency</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farm size</strong></td>
<td>Kompas (2004); Fabiosa et al. (2004); Brázdik (2006); Vu (2008); Javed et al. (2010)</td>
</tr>
<tr>
<td><strong>Land fragmentation</strong></td>
<td>Wadud and White (2000); Brázdik (2006); Rahman and Rahman (2008)</td>
</tr>
<tr>
<td><strong>Family Labour size</strong></td>
<td>Coelli et al. (2002); Dhungana, et al. (2004); Vu (2008); Rahman and Rahman (2008); Mariano et al. (2010)</td>
</tr>
<tr>
<td><strong>Education of farm head</strong></td>
<td>Dhungana, et al. (2004); Amaza and Maurice (2005); Villano and Fleming (2006); Asadullah and Rahman (2009); Javed et al. (2010); Mariano et al. (2010); Huynh and Yabe (2011)</td>
</tr>
<tr>
<td><strong>Age/ Experience</strong></td>
<td>Coelli et al. (2002); Dhungana, et al. (2004); Amaza and Maurice (2005; Villano and Fleming (2006); Vu (2008); Javed et al. (2010); Mariano et al. (2010)</td>
</tr>
<tr>
<td><strong>Off-farm income</strong></td>
<td>Coelli et al. (2002); Villano and Fleming (2006); Rahman and Rahman (2008)</td>
</tr>
<tr>
<td><strong>Extension services</strong></td>
<td>Adesina and Djato (1996); Rahman and Rahman (2008); Javed et al. (2010)</td>
</tr>
<tr>
<td><strong>Access to credit</strong></td>
<td>Adesina and Djato (1996); Kompas (2004); Javed et al. (2010)</td>
</tr>
<tr>
<td><strong>Environmental degradation</strong></td>
<td>Wadud and White (2000)</td>
</tr>
<tr>
<td><strong>Irrigation/ Infrastructure</strong></td>
<td>Wadud and White (2000); Coelli et al. (2002); Huynh and Yabe (2011)</td>
</tr>
</tbody>
</table>

Previous studies have consistently shown that land fragmentation is negatively correlated with technical efficiency of rice farms. Rahman and Rahman, (2008) found that a decrease in number of plots cropped by farms raised technical efficiency of farms. Farm households with greater plot size (lower land fragmentation) are more likely to apply new technologies such as tractors or irrigation, resulting in the higher technical efficiency of these farms (Wadud and White, 2000; Brázdik, 2006).
In terms of farm size, most studies have shown that the lower the farm size, the lower technical efficiency of farms (Kompas, 2004; Fabiosa et al., 2004; Brázik, 2006; Vu, 2008). The exception is Javed et al. (2010). Examining the rice-wheat system in Pakistan, Javed et al. (2010) found there was an inverse relationship between technical efficiency and farm size.

Studies on the relationship between numbers of farm household members or number of working members and technical efficiency in rice-based farming are inconclusive. Coelli et al. (2002) and Mariano et al. (2010) found the negative impact of family size on technical efficiency in Bangladesh and Philippines, indicating that large families were likely to be more inefficient. On the other hand, Brázdik (2006) and Rahman and Rahman (2008) estimated that the number of working members in a farm family raised technical efficiency of rice farms in Java Indonesia and Bangladesh, respectively. Dhungana, et al. (2004) found an insignificant positive impact of share of family labour in rice production.

In terms of education of farmers, while the vast majority of studies find that lower years of schooling of farm heads reduces technical efficiency (Dhungana, et al., 2004; Villano and Fleming, 2006; Asadullah and Rahman, 2009; Mariano et al., 2010; Huynh and Yabe, 2011), the effect of education on technical efficiency is slightly ambiguous. Coelli et al. (2002) and Rahman and Rahman (2008) failed to identify any significant impact of farmer’s education on technical efficiency of rice farms in Bangladesh. A Vietnamese study (Vu, 2008) found insignificant negative impacts of secondary and higher education on technical efficiency. Farmers with higher
education tend to shift to non-farm activities, therefore their education does not contribute to technical efficiency.

Agricultural extension can be regarded as one of the important sources of information that is directly relevant to agricultural production practices, particularly in countries where farmers have very limited access to information. This is reinforced by the fact that many studies found a significant influence of extension education on adoption of modern technologies (Adesina and Zinnah, 1993; Baidu-Forson, 1999), and technical efficiency in rice-based farming (Rahman and Rahman, 2008 and Javed et al. 2010). The evidence indicates that extension services are positively associated with technical efficiency of farms.

Other factors that significantly impact on technical efficiency include age of farmers and years of experience in farming. Many studies have shown that younger farm heads are more technically efficient than older farm heads. (Coelli et al., 2002; Dhungana, et al., 2004; Villano and Fleming, 2006; Vu, 2008; Javed et al., 2010; Mariano et al. 2010). Amazu and Maurice (2005) and Mariano et al. (2010) found a significantly positive influence of farming experience on technical efficiency.

Technical efficiency of rice-based farms is also influenced by off-farm work. The evidence indicates that off-farm income is negatively correlated with technical efficiency in rice farms (Villano and Fleming, 2006). This is also observed in the relationship between off-farm income
share, which is the ratio of off-farm income to total income, and technical efficiency. Coelli et al., (2002) found that farms with lower off-farm income share are more likely to have higher technical efficiency.

In addition, access to credit, irrigation and environmental degradation impact on technical efficiency in some studies. Rice-based cropping system may be influenced by access to irrigation. For example, in the rice-based cropping system in Bangladesh, the expansion of non-cereals stagnated due to their incompatibility with the existing modern irrigation systems (Mahmud et al., 1994). The findings by Wadud and White (2000) indicated that irrigation schemes operated with diesel increased technical inefficiency in Bangladesh. In Vietnam, Huynh and Yabe (2011) found that irrigated farms produced rice more efficiently than farms in the non-irrigated regions. Wadud and White, (2000) found that farms with good quality of soils were less technically inefficient. In term of access to credit, Javed et al. (2010) found that farms with better access to credit were technically more efficient than those that had poor or no access to credit. For Vietnamese rice farming, Kompas (2004) also stressed the important role of credit.

Rahman (2009) found strong evidence of diversification economies among rice-based farms (except for the combination of modern rice and modern wheat enterprises). The gain in technical efficiency from crop diversification is highest with the combination of modern rice and cash crops. The combination of crops is explained by better use of household labour (avoiding bottlenecks in labour usage) and using less purchased inputs, particularly pesticides and fertilisers.
Table 2.4: Research on technical efficiency in rice-based diversified crops

<table>
<thead>
<tr>
<th>References</th>
<th>Country</th>
<th>Agricultural system</th>
<th>Technical efficiency level (Full efficiency = 100)</th>
<th>Determinants of technical efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaza and Maurice (2005)</td>
<td>Nigeria</td>
<td>Rice-maize</td>
<td>80</td>
<td>Education;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rice-cocoyam</td>
<td></td>
<td>Farming experience</td>
</tr>
<tr>
<td>Rahman (2009)</td>
<td>Bangladesh</td>
<td>Rice-Wheat</td>
<td>84</td>
<td>Crop diversification;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rice-cash crops</td>
<td></td>
<td>Education of farmers;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Experience; Family size;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Share of off-farm income</td>
</tr>
<tr>
<td>Javed et al. (2010)</td>
<td>Pakistan</td>
<td>Rice-Wheat</td>
<td>83</td>
<td>Farm size;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Education of farmers;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extension service; Access to credit;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Age of farmers; Farm to market distance</td>
</tr>
</tbody>
</table>

The literature review in the context of rice-based farming (including rice-only farming as well as rice-based diversified farming) has been used to select the determinants of technical efficiency to be tested for this thesis. The determinants selected include farm size, land fragmentation, crop diversification, family labour, off-farm work and education and age of farmers, irrigation, access to credit to estimate the determinants of technical efficiency. However, information on some variables of interest, to examine such factors as irrigation and access to credit, are not available in the data set selected in this research, thus this thesis will examine these determinants excluding extension service, access to credit, irrigation and environmental degradation.
2.5 Assessing the literature

Reviewing the literature is important to reach a better understanding of what can impact on technical efficiency of farms, particularly in the rice based cropping context. In summary, from the literature examined, it has been possible to provide a theoretical foundation for the thesis. Previous research has uncovered some issues associated with factors of farm size and land fragmentation in investigating efficiency in rice-based diversified cropping context and points to the necessity of understanding crop diversification.

The literature has also revealed the inverse relationship between farm size and productivity; technical efficiency could be true when smaller farms are more productive because land is used more intensively or more efficiently allocate labour. This thesis tests whether the relationship farm size and technical efficiency is inverse when land use of farm households is fragmented and even farms apply crop diversification it is essential to show the relationship between technical efficiency and farm size, land fragmentation and crop diversification.

The evidence reviewed in this chapter reveals that several variables have been introduced in models seeking to explain farm level variation in technical efficiency. In the summary, from results of research, the determinants that have been found in rice-based farming are: farm size, land fragmentation, family labour size, farmer’s education, age and experience, contacts with extension, access to credit, irrigation, soil fertility and off-farm income. With the exception of farm size, land fragmentation, family labour size and age, the results reveal that these variables
tend to have a positive and statistically significant impact on technical efficiency. In general, these results are consistent with the findings reported in the frontier function literature review (Bravo_Ureta and Pinheiro, 1993).

This thesis, by investigating technical efficiency and its determinants in annual crops, contributes to new knowledge on Vietnam’s agriculture system because it measures the technical efficiency in annual crops. It also analyses the impact of farm size, land fragmentation, crop diversification and other factors on the context of mixed crops. Other researchers on Vietnam only examined the impact of farm size in individual crop such as rice. This thesis will contribute to the literature in the field of the relationship of crop diversification and efficiency.
Chapter 3  FACTORS TO BE TESTED FOR

3.1 Introduction

The main research question is: “What are the determinants of technical efficiency of annual cropping on farms in the Northern region of Vietnam?” To answer the research question a general option was estimated which included the variables identified in the literature. The first hypothesis relates to the efficiency among farms. The second hypothesis tests if there is increasing returns to scale. In addition, other variables were selected as possible determinants of farm technical efficiency. The review of the literature in Chapter 2 found that farm size, land fragmentation, crop diversification and other factors such as family labour size, education, age of farm head and off-farm income might impact on technical efficiency. This thesis uses these factors to estimate the determinants of technical efficiency of farms in the North. Variables used in this thesis are: farm size (in land area and total output value of crops), land intensity, number of plots, family labour size, ratio of land to family labour, education of farm head (primary, secondary and high school level), age of farm head, ratio of off farm income to total income and crop diversification variables (Herfindahl index and Ogive index).

Section 3.2 identifies the expected determinants of technical efficiency. Section 3.3 summarises the hypotheses and defines variables used for testing the hypotheses. A summary of the chapter is presented in section 3.4.
3.2 Expected determinants of efficiency

3.2.1 Farm size

The literature discussed in Chapter 2 indicated that technical efficiency of farms might depend on farm size. Smaller farms have more advantages because they may use land more intensively and be managed properly by utilising their household labour and hired labour. The positive relationship between farm size and technical efficiency is tested in this thesis. There are two aspects. First, the inverse relationship between farm size and technical efficiency might be weak. The findings that smaller farms are more productive because land is used more intensively, have largely concentrated on partial productivity measures, typically yields per hectare, with size measured in term of total hectares managed and have often failed to account for the differential use of other inputs (Gorton and Davidova, 2004). The inverse relationship between the size of land holdings and productivity has been weakened in recent times due to the availability of size-neutral biotechnology such as seed, fertiliser and differences in management input. Additionally, according to Niroula and Thapa (2005), the inverse relationship between landholdings and productivity may be only relevant in the subsistence economy, where there is no competition between farmers with varying landholding size. In the Northern region of Vietnam, farms are diversified with partly marketed products and small farms have to compete with large farms for selling outputs. The technical efficiency of farms depends on market costs of production where the large farms may have advantages competing with small farms. Several empirical findings provide evidence that larger farms are more technically efficient than small farms. Second, the impact of fragmentation of land parcels might mitigate the theoretical of inverse relationship
In the case of the North, land fragmentation may limit any inverse relationship between farm size and technical efficiency.

Empirical evidence is somewhat contradictory regarding an inverse relationship between size of farm and output per unit of land in Vietnam (Akram-Lodhi, 2001) and between farm size and technical efficiency (Vu, 2008).

### 3.2.2 Land fragmentation

The fragmentation of land may impact on the technical efficiency of farms. A larger number of plots may hamper a farm’s technical efficiency. Landholding is fragmented into several tiny plots with varying distance from the farmhouse, which leads to increased transaction costs of use and undermines operational efficiency. Additionally, when land parcels are dispersed, the input use efficiency is reduced, resulting in increased costs of production and reduced net return per unit of land and labour, this constrains production by weakening farmers’ competition capacity (Pham, 2007; Niroula and Thapa, 2005, 2007). Rahman and Rahman (2008) provided evidence that an increase in land fragmentation reduces technical efficiency. Based on the above argument and on the literature review discussed in Chapter 2, the present thesis tests the hypothesis that the number of plots of land per farm and technical efficiency are negatively associated.
3.2.3 Land use intensity

Land is the principal farming input. It is a fixed factor of production. Technologies which increase the intensity of land use (in other words, the number of times a piece of land is used to grow crops in a single year) such as transplanting, fast maturing crops, irrigation and fertiliser are likely to have a positive impact on farm technical efficiency. Land use intensity is measured as the ratio of the total area used for annual crops divided by land area managed by a farm. The literature stresses that difference in the intensity of land use across farms of different sizes influences land productivity. Chand et al. (2011) suggested that land use intensity is likely to increase land productivity of farms. The technical efficiency of farms may depend positively on land use intensity.

3.2.4 Family labour size

Household size is measured by the number of people in a farm household. The literature suggests that household size is a demographic factor which can impact on a farm’s technical efficiency. A larger household size is likely to have disadvantages. A larger family may cause lower technical efficiency in less labour-intensive crops, when surplus labour may be a problem. This means that surplus farming labour may constrain farm production by choosing less efficient cropping systems. According to Lau and Yotopoulos (1971) and Getachew (1995), the impact of household size could be an indication of labour-intensive crop production. Moreover, Coelli et al., (2002), Binam et al. (2003), Haji (2006), Bozoglu and Ceyhan (2007) and Vu (2008) provided evidence on developing countries, that more family members were likely to decrease
technical efficiency of farms. It is argued that the negative relationship between family size and technical efficiency highlights hidden unemployment. Thus, it is important to examine this impact on technical efficiency of farms.

Research on rice farming has focused on family labour instead of household size to examine the impact of labour use on technical efficiency. For example, Dhungana et al. (2004) and Brázdik (2006) used the share of family labour; Villano and Fleming (2006) used the ratio of adults to children; Rahman and Rahman (2008) used the number of working members in a family as appropriate variables. In this thesis, the hypothesis that the number of family members working on the farm and technical efficiency are negatively associated will be tested.

3.2.5 Ratio of land to family labour

Labour use can be compared with farm area to examine whether surplus labour of farms may impact on technical efficiency. Fan and Connie (2005) showed that to increase labour productivity, either land productivity or land to labour ratio has to increase. If farm labour is a fixed factor of production (surplus labour lacking alternative uses) and land is fixed it will be difficult to adopt a technically efficient land labour ratio. Vu (2008) suggested that a higher land to labour ratio leads to increase technical efficiency. This thesis will test the hypothesis that the ratio of land to family labour and technical efficiency are positively associated.
3.2.6 Education

In the literature on determinants of technical efficiency, variables related to the farm head have been used as measures of management skill. The person who is responsible for managing the farm household business is called the “farm head”. The literature reviewed in Chapter 2 indicates that the education of the farm head can be used as a proxy for managerial input. It is commonly believed that a higher level of education may lead to better management of farming practices. Many studies such as Ali and Flim (1989), Dhungana et al., (2004), Javed (2009) and Mariano et al., (2010) used the year of schooling completed by the farm head as the variable affecting technical efficiency. Year of schooling as a variable is known to be positively related to technical efficiency. This implies that farmers with more years of schooling are more technically efficient than those with less or no years of schooling. It is argued that better educated people adopt and use modern inputs more optimally and efficiently. Ahmad, et al. (2002) argued that the educated farmers usually have better access to information about the state of technology and its use. More years of schooling creates awareness of new technology among farmers and thus educated farmers get better yields.

The literature supports the use of education levels to examine the impact on efficiency. This is because each level of education (primary school, secondary school, high school) will have different impact on farm efficiency. In the north of Vietnam, most farms are characterized by small land size, abundant agricultural labour and low technology. In this case, levels of education might have a different impact on technical efficiency. The farmers completing primary school have a higher tendency to use inputs more efficiently compared to farmers without formal
education. However, better educated farmers with a high level of education may have better access to non-farm jobs, thus reducing the intensity of engagement in farm management. Vu (2008) showed evidence of the importance of primary education rather than secondary or higher education for improving farm’s technical efficiency. Rio and Shively (2005) argued that efficiency falls with higher levels of education on small farms because education increases opportunities for off-farm work and thereby reduces on-farm management intensity. Therefore, education levels should be investigated as a determinant of technical efficiency. The definition of these education variables is presented in section 3.3 of this chapter.

3.2.7 Age of farm head

Age of farm’s operator may be an important factor in decision making. It is generally believed that age serves as a proxy for farming experience. The older farmers are likely to have more experience and hence be more productive. On the other hand, it is also possible that the older farmers may be traditional and conservative and show less willingness to adopt new farming technology and therefore, be less efficient. The literature on rice-based farming suggests age of farm head has a negative impact of technical efficiency.
3.2.8 The share of off-farm income

Off-farm work of farmers is a determinant of technical efficiency in developing countries, according to empirical literature. It is claimed that farm households in developing countries may be too small to focus only on farm activity.

The factor of off-farm activity is usually measured by whether there is off-farm income. In this case, the variable is coded as “1” if the farm household earns off/non-farm income and “0” otherwise. Parikh et al. (1995) and Raman and Rahman (2008) used the allocation of time to off-farm work as an independent variable to impact on technical efficiency. Another measure of non-farm work is the share of total income received from off-farm work. This variable is included to reflect the relative importance of non-agricultural work when farm households do not fully support themselves through agriculture. This variable was applied by Coelli et al. (2002); Chavas et al., (2005) and Vu (2008).

There is evidence that off-farm work has a negative influence on technical efficiency in rice farming as well as in other cropping but this is inconsistent in the findings by Haji (2006) and Solis et al. (2009). Haji (2006) found that non-farm income had a significant and positive impact on technical efficiency in the context of crop diversification of vegetables. It is argued that off-farm employment absorbs under-employed labour resources. Especially, it may improve the experience and human capital of the farm operator and bring additional income that could be used for farm activities (Haji, 2006). The interesting finding by Solis et al. (2009) showed that
for farms engaged mainly in staple production, it would be difficult to achieve productivity gains by pursuing off-farm activities, while farms diversifying towards cash crops would have a positive association between technical efficiency and off-farm income. Thus, it is expected that there is a positive relationship between off-farm work and technical efficiency in the context of mixed crops.

In the case of Northern Vietnam, income diversification including off-farm work plays an important role in household income of farm households (Minot et al., 2006). Therefore, the share of off-farm income is chosen to examine the impact on technical efficiency.

3.2.9 Crop diversification

To explore the impact of crop diversification, various studies have used the use of a number of crops as a proxy for the level of diversification. However, in this thesis, the variables to examine crop diversification are similar to that used by Coelli and Fleming (2004) and Rahman (2009). In their studies, the Herfindahl index and the Ogive index are measures of the concentration of output or specialisation. It means that a negative sign on the coefficient of these variables on technical efficiency or a positive sign on inefficiency indicate the positive impact of crop diversification on technical efficiency. The results in both studies are consistent with findings that crop diversification impacts positively on technical efficiency. These studies found that crop diversification had a positive impact on technical efficiency in crop systems that combine cash cropping and subsistence food crop production.
3.3 Definitions of variables

Technical and scale efficiency are derived from the definition of DEA discussed earlier. If the mean of technical and scale efficiency scores (derived from DEA) is less than 1, there is inefficiency. Thus there is room to increase efficiency.

Farm size

Measures of output or input can be chosen as measure of farm size. In this thesis, the independent variables tested are *land area* and *total output value* to examine the significance of each measure and get better understanding of farm size.

Land area (LANDAREA) is the total annual land area managed by each farm.

Total output values (TOTALOUTPUT) is the total value of annual crop outputs including rice, starchy crops, vegetables, and industrial annual crops of each farm.

Land fragmentation

The independent variable tested is the *number of plots per farm*.

Number of plots (NUMBEROFPLOT) is the number of plots for annual crops per farm.

Land intensity

The independent variable tested is the *ratio of land cropped* to total annual cropping area of each farm.
Ratio of land cropped (LANDINTENSITY) is considered as the ratio of the total annual cropped area (sum of area for all annual crops in a year) divided by total land area available for annual crops per farm (total annual land area managed).

*Family labour size*

The independent variable tested is the *family labour size*.

Family labour size (FAMILYLABOUR) is the number of family members working on the farm.

*The ratio of land to family labour*

The independent variable tested is *land for annual crops to family labour*.

Land for annual crops to family labour (square meters/hour) (LANDTOLABOUR) is the annual land area divided by the total hours worked by family members on the farm.

*Education level of farm head*

The independent variables tested are dummy variables for primary level, secondary level and high school level. Primary education is chosen as the omitted category.

**Primary level (PRIMARY)** is a dummy variable defined as 1 if farm head completed at least one class in primary level (year 0, 1, 2, 3, 4 or 5) and 0 otherwise.

**Secondary level (SECONDARY)** is a dummy variable defined as 1 if the farm head completed at least one class in secondary level (year 6, 7, 8, 9) and 0 otherwise.
High school (HIGHSCHOOL) is a dummy variable defined as 1 if the farm head completed at least one class in high school level (year 10, 11, 12 and more) and 0 otherwise.

*Age of farm head*

The independent variable tested is age of farm head.

*Age of farm head (AGE)* is the age of the farm head.

*Share of off-farm income of farm*

The independent variable tested is the share of off-farm income of farm in total income.

*Share of off-farm income (OFFFARM)* is a ratio of off-farm income divided by the total income of a farm.

*Crop diversification*

The independent variables tested are the Herfindahl and Ogive indexes. These indexes are measures of concentration of crop shares using land cropped and value of crop produced. They measure crop specialisation.

This study tests each of these indexes in separate models because they are different ways to measure crop diversification.

*Herfindahl index (HERFINDAHL)* ranges from zero for complete diversification to one for complete specialisation, it is calculated as:

\[ H = \sum(P_i^2) ; 0 \leq H \leq 1 \]

where \( P_i \) is the proportion of land under the \( ith \) crop relative to the total land area cropped. \( P_i \) represents the land area shares occupied by the \( ith \) crop group in total area used by a farm. A
negative coefficient on the Herfindahl index indicates that technical efficiency is negatively associated with crop specialisation, which implies that crop diversification, therefore, improves technical efficiency.

Ogive index (OGIVE) is defined as the concentration of output shares. This index measures deviations from an equal distribution of output shares between crops. The higher value of Ogive index indicates the higher level of specialisation. The negative coefficient of Ogive index on the efficiency variable indicates that greater specialisation leads to smaller technical efficiency, suggesting the benefits of crop diversification.

\[ Ogive = \sum \frac{(X_i - \frac{1}{N})^2}{1/N} \]

\( N \): total number of crops under consideration

\( X_i \): share of output value of ith crop.
3.4 Summary

Table 3.1: Determinants of technical efficiency hypotheses

<table>
<thead>
<tr>
<th>Factors</th>
<th>Symbol of variable</th>
<th>Expected sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size</td>
<td>LANDAREA</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>TOTALOUTPUT</td>
<td></td>
</tr>
<tr>
<td>Land fragmentation</td>
<td>NUMBEROFPLOT</td>
<td>-</td>
</tr>
<tr>
<td>Land intensity</td>
<td>LANDINTENSITY</td>
<td>+</td>
</tr>
<tr>
<td>Family labour size</td>
<td>FAMILYLABOUR</td>
<td>-</td>
</tr>
<tr>
<td>Ratio of land to family labour</td>
<td>LANDTOLABOUR</td>
<td>+</td>
</tr>
<tr>
<td>Education of farm head</td>
<td>SECONDARY</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>HIGHSCHOOL</td>
<td></td>
</tr>
<tr>
<td>Age of farm head</td>
<td>AGE</td>
<td>-</td>
</tr>
<tr>
<td>Share of off-farm income</td>
<td>OFFFARM</td>
<td>+</td>
</tr>
<tr>
<td>Crop diversification</td>
<td>HERFINDAHL</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>OGIVE</td>
<td></td>
</tr>
</tbody>
</table>

This chapter is based on the empirical literature. It covered the hypotheses developed for this thesis. The chapter has identified the direction of the impact of the independent variables on the technical efficiency of a farm. In this context of land-scarcity, high level of land fragmentation and family labour size are expected to reduce technical efficiency of farms. Age of farm head may also have negative impact. On the other hand, farm size, land intensity, ratio of land to...
family labour, education of farm head, off-farm income and crop diversification are expected to have positive impacts on technical efficiency.
Chapter 4 DATA AND METHODOLOGY

4.1 Introduction

This chapter discusses the research design used in this thesis. The research design includes the sampling procedure, technical efficiency measurement and Tobit regression analysis.

The rest of this chapter is organised as follows. Section 4.2 describes the source of the data used in this study. Section 4.3 explains the sample selection procedure and sample description. Section 4.3.1 describes the study area. Section 4.3.2 provides the reasons for choosing the sample used. Section 4.3.3 describes general characteristics of farms in the sample. Section 4.4 presents the models to test the hypotheses. Section 4.4.1 shows the Data Envelopment Analysis (DEA) models which estimate technical efficiencies used to test the first two hypotheses. Section 4.4.1.1 presents a DEA model to estimate the total technical efficiency. Section 4.4.1.2 presents a DEA model to estimate pure technical efficiency. Section 4.4.1.3 describes the model used to calculate scale efficiency. Section 4.4.1.4 highlights the bootstrap method which is used to test the bias of efficiency estimates from DEA. Section 4.4.1.5 defines variables used in DEA models. Section 4.4.2 presents the Tobit analysis. Section 4.4.2.1 describes the empirical model of Tobit regression. Section 4.4.2.2 discusses the use of goodness of fit tests for the regression model. Section 4.4.2.3 describes significance testing of the regression models. Section 4.4.2.4 highlights the definition and predicted signs of the independent variables in the Tobit regression models. Section 4.5 summarises this chapter.
4.2. Data sources

The major data source used in this research is from the *Vietnam Household Living Standard Survey 2006-2008* (VHLSS 2008). VHLSS is a multi-purpose national survey investigating living standards in Vietnam. The survey was conducted by the General Statistics Office of Vietnam with technical support from the World Bank. The *Vietnam Household Living Standard Survey* series from 2002 to 2010 was based on a master sample for sample selection. The master sample was a random sample of households from the 1999 Population Census enumeration areas. The target population of the VHLSS was comprised of the civilian, non-institutionalised population of Vietnam. In order to cover this target population, interviews are conducted at the household level (VHLSS, 2008b).

<table>
<thead>
<tr>
<th></th>
<th>Urban areas</th>
<th>Rural areas</th>
<th>All areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of households (1,000)</td>
<td>4,026 (24%)</td>
<td>12,635 (76%)</td>
<td>16,661</td>
</tr>
<tr>
<td>Number of EAs</td>
<td>38,435 (23%)</td>
<td>128,085 (77%)</td>
<td>166,520</td>
</tr>
<tr>
<td>Number of communes/wards</td>
<td>1,561 (15%)</td>
<td>8,915 (85%)</td>
<td>10,476</td>
</tr>
<tr>
<td>Households per EA</td>
<td>105</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Households per commune/ward</td>
<td>2,579</td>
<td>1,417</td>
<td>1,590</td>
</tr>
<tr>
<td>Number of EAs per comm./ward</td>
<td>25</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: VGSO, 2005

Note: EA is enumeration area

The master sample used in the VHLSS is a three-stage area sample where communes are selected in the first stage, three enumeration areas (EA) per commune are selected in the second
stage and households randomly selected at the third stage. This is a standard design used for household surveys worldwide (VGSO, 2005).

The communes are stratified within provinces and the sample is selected randomly over strata proportional to the square root of the number of households. Both communes and EAs are selected with probability proportionate to size, the size being the number of households according to the Population Census 1999. However, because some communes/wards are quite large and some are too small, there would be difficulties in implementing fieldwork. So, a second stage of selection in which three EAs and a minimum size of 300 households per commune were selected to serve as a sampling unit of the master sample for VHLSS.

The surveyed households in each selected EA were selected from the most updated list of the households in these selected EAs and weights used to readjust for population change. Moreover, the sample design used in the VHLSS was a three-stage stratified cluster design. Households in the sample were clustered within sampled areas to save travel and administrative costs. According to the methods for optimising the size of clusters that the General Statistics Office of Vietnam uses, for the VHLSS, an optimal cluster size would be 10 in urban areas and 20 in rural areas. However, after considering the high costs of implementing the survey in a large number of clusters, the final cluster size is selected to be 25 households and EAs with minimum size of 70 households are needed for selection of 25 households per cluster (VGSO, 2005).
4.3. Sampling procedure

4.3.1 Selection of study areas

This study used farm-level, cross-sectional data for the year 2008, for annual crops selected from two regions in Northern Vietnam. The selected data consisted of farm households collected by VHLSS 2008 in four provinces: Phu Tho, Yen Bai, Hung Yen and Thai Binh. These provinces were chosen for three reasons. First, they represent different ecological regions in the northern part of Vietnam. Phu Tho and Yen Bai provinces are located in the North-East, Hung Yen and Thai Binh in the Red River Delta region. Also, Phu Tho and Yen Bai are located in the centre of the mountainous provinces in the North. They were chosen for the sample because the ability of farmers to speak Vietnamese is high in Phu Tho and Yen Bai. The proportion of farm heads who could speak Vietnamese in Phu Thu and Yen Bai is 100 and 99.4 per cent, respectively, compared to other provinces where the proportion is lower. In Lai Chau, for example, 70 per cent of farm heads speak Vietnamese. The proportion of farm heads who can read and write in Phu Tho is 98 per cent compared to 61 and 69 per cent in Lai Chau and Dien Bien, respectively. These proportions are also extremely high in the delta areas. According to VHLSS 2008, illiteracy is a serious problem in some northern mountain areas where the proportion of ethnic minorities is high. It can lead to big differences in production level between regions. This thesis does not cover questions about the determinants of technology, thus provinces were selected to remove differences in illiteracy. Second, outputs of farms in the sample are similar. Farms in these four provinces mainly grow rice, starchy crops, vegetables and industrial annual crops in
land for annual crops. Finally, farms in the sample were chosen randomly. The sample was collected by VGSO from 161 areas and 179 communes.

**Table 4.2: The number of enumeration areas, communes in the selected sample**

<table>
<thead>
<tr>
<th></th>
<th>Number of farms</th>
<th>Number of EA</th>
<th>Number of communes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phu Tho</td>
<td>106</td>
<td>39</td>
<td>45</td>
</tr>
<tr>
<td>Yen Bai</td>
<td>77</td>
<td>23</td>
<td>29</td>
</tr>
<tr>
<td>Hung Yen</td>
<td>99</td>
<td>40</td>
<td>44</td>
</tr>
<tr>
<td>Thai Binh</td>
<td>165</td>
<td>59</td>
<td>61</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>447</strong></td>
<td><strong>161</strong></td>
<td><strong>179</strong></td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2008

### 4.3.2 Sample selection

In the study area, there were 106, 77, 99 and 165 farms listed on the VHLSS 2008, located in Phu Tho, Yen Bai, Hung Yen and Thai Binh, respectively (See Table 4.2). In total, there are 447 farms in the sample. Detailed crop input-output data for individual farms were selected for annual crops. Among other variables, the dataset also includes information on total output values, cropped land area, number of plots, ratio of land cropped, family labour, characteristics of farm head such as education and age, off-farm income and crop diversification. From the 447 farms, there were 10 farms which did not use family labour for agricultural activities that are excluded from the sample. This means that in these farms, the value of inputs “family labour” was equal to zero, perhaps as a result of a measurement error. Moreover, there were 14 observations considered as outliers. These were excluded because compared with other observations in the sample, their ratio of total value of outputs and total value of inputs were extremely different from others. This research used Data Envelopment Analysis (DEA) to
estimate technical efficiency. DEA is a computationally convenient way to measure efficiency that does not require an explicit functional relationship between inputs and outputs. However, because the frontier is constructed using extreme observations, DEA can be sensitive to extreme points, especially when data may be contaminated by measurement error therefore outliers are excluded. Finally, 423 farms were used to estimate technical efficiency.

4.3.3 General farm characteristics

Farms in the sample are categorised as small farms. Annual cropping land area managed by farms ranges from 505 square metres to 20,880 square metres, with a mean of 2,786 square metres. The mean farm size is higher in Yen Bai than in other provinces. Farms have an average of 3.4 plots with the number ranging from a minimum of 1 to a maximum of 12. The majority of farms have between three and five plots. Only 1.9 per cent of farms have more than nine plots, of which the figure for Phu Tho is 5.8 per cent (See Table 4.3).

The sampled farms planted rice, starchy crops (including maize, sweet potatoes, cassava), many kinds of vegetables and annual industrial crops (such as peanuts, soybeans, sesame seeds). These four groups of crops are classified in this thesis as “rice”, “starchy crops”, “vegetable” and “annual industrial crops”. Farms are classified as producing one group if outputs of farms belong to one in these four crop groups. Farms are classified as diversified with two crop groups if outputs of the farms belong to two of the four groups. Farms are classified as diversified with
three crop groups if outputs of farms belong to three of the four groups and farms with four if farms plant all four groups of crops (See Table 4.3).

### Table 4.3: Farms in the sample

<table>
<thead>
<tr>
<th>Provinces</th>
<th>Phu Tho</th>
<th>Yen Bai</th>
<th>Hung Yen</th>
<th>Thai Binh</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Northeast</td>
<td>Northwest</td>
<td>Red River Delta</td>
<td>Red River Delta</td>
<td></td>
</tr>
<tr>
<td><strong>No of farms</strong></td>
<td>103</td>
<td>70</td>
<td>93</td>
<td>157</td>
<td>423</td>
</tr>
<tr>
<td><strong>Land area (square metres)</strong></td>
<td>Mean</td>
<td>2,810</td>
<td>4,769</td>
<td>2,222</td>
<td>2,219</td>
</tr>
<tr>
<td><strong>No of plots (per cent)</strong></td>
<td>&lt; = 2</td>
<td>22</td>
<td>58</td>
<td>37</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>53</td>
<td>40</td>
<td>53</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>6-8</td>
<td>19</td>
<td>2</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>&gt;= 9</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Group of crops grown per farm</strong></td>
<td>1 group</td>
<td>2 groups</td>
<td>3 groups</td>
<td>4 groups</td>
<td>All farms</td>
</tr>
<tr>
<td><strong>No of farms</strong></td>
<td>88</td>
<td>117</td>
<td>156</td>
<td>62</td>
<td>423</td>
</tr>
<tr>
<td><strong>Land area</strong></td>
<td>Mean</td>
<td>1,803</td>
<td>2,557</td>
<td>3,329</td>
<td>3,243</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>505</td>
<td>528</td>
<td>696</td>
<td>648</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>6,120</td>
<td>19,500</td>
<td>20,880</td>
<td>20,000</td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2008 for 4 provinces (Phu Tho, Yen Bai, Hung Yen and Thai Binh)

As Table 4.3 shows, the proportion of farms with crop diversification is remarkably high with 335 of the 423 farms growing two of the crop groups. Traditionally, rice is the main crop produced in Vietnam and is planted in every province. In the sample, rice is the most popular crop among annual crops. As Table 4.4 shows, 413 of the 423 farms were producing rice compared with 226 farms growing groups of starchy crops, 290 vegetables and 113 annual
industrial crops, out of the 423. Of the 413 farms producing rice, 161 farms cultivate rice only for consumption, while none of the farms sell all their rice production. Table 4.4 shows that farms sell on average 23 per cent of their output of rice and 37 per cent output of starchy crops, 29 per cent vegetable, and 61 per cent output of annual industrial crops. Clearly, farm consumption is very important in these farms but a part of the output is marketed.

Table 4.4: Percentage of crops sold in markets

<table>
<thead>
<tr>
<th></th>
<th>Rice</th>
<th>Starchy crops</th>
<th>Vegetables</th>
<th>Annual industrial crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms producing crops</td>
<td>413</td>
<td>226</td>
<td>290</td>
<td>113</td>
</tr>
<tr>
<td>Number of farms consuming all output</td>
<td>161</td>
<td>109</td>
<td>149</td>
<td>30</td>
</tr>
<tr>
<td>Number of farms selling all output</td>
<td>0</td>
<td>17</td>
<td>3</td>
<td>18</td>
</tr>
</tbody>
</table>

Percentage of crop sold

<table>
<thead>
<tr>
<th>Mean</th>
<th>23</th>
<th>37</th>
<th>29</th>
<th>61</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Max</td>
<td>97</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2008

As Figure 4.1 shows 78 per cent of farms in the sample grow diversified crops including rice, while 20 per cent of farms grow only rice. Only 2 per cent of farms cultivate other annual crops without rice. The sampled farms are focused on rice-based farming.
4.4. Research design

Given the objectives and hypotheses explained in the previous chapters, the method used should permit measurement of efficiencies which account for total technical efficiency, pure technical efficiency and scale efficiency. This thesis uses Data Envelopment Analysis (DEA) to estimate these efficiencies. The thesis follows two steps of analysis. The first step is to calculate the total technical, pure technical efficiency, scale efficiency scores on a sample of farms by using DEA. Technical efficiency scores can be obtained by estimating a constant returns to scale DEA model or variable returns to scale DEA model. Technical efficiency scores obtained from a constant
return to scale DEA model are called the total technical efficiency scores and from a variable
return to scale DEA model as pure technical efficiency scores (See section 2.3.2). Scale
efficiency measures the optimality of the firm’s size. It is obtained by dividing the total technical
efficiency by pure technical efficiency (Collie et al., 2005). In the second step, the efficiency
scores are regressed on different combinations of explanatory variables to explore the
determinants of technical efficiency.

4.4.1 Measurement of efficiencies

Technical efficiency relates to the degree to which a farmer produces the maximum feasible
output from a given bundle of inputs, or uses the minimum feasible amount of inputs to produce
a given level of output. These two definitions of technical efficiency are known as output-
oriented and input-oriented efficiency measures, respectively. Coelli, et al. (2002) suggested
selecting between an input-oriented DEA model or output-oriented DEA model according to
which quantities (inputs or outputs) the manager of a farm has more control over. As, farmers
have more control over inputs than output, input-orientated DEA models are used in this thesis.

The efficiency of a farm relative to other farms is calculated by forming an index of the ratio of a
weighted sum of outputs to a weighted sum of inputs. With the DEA approach, multiple inputs
and multiple outputs are reduced to a single virtual input and virtual output and finally to a single
summary relative efficiency score. DEA proposes that each farm should be allowed to adopt a set
of weights which shows it in the most favourable light in comparison to the other farms. This
means that the values of weights for outputs and inputs \((u’s \text{ and } v’s)\) are not established from empirical data but are estimated from the model with the help of programming techniques (Hartwich and Kyi, 1999).

We have data on K inputs and M outputs of N farms. The ratio of output to input then measures the efficiency of a particular farm in the sample. For example, the efficiency of farm i would be computed according to:

\[
E_i = u_1 y_{1i} + u_2 y_{2i} + \ldots + u_m y_{mi} / \left( v_1 x_{1i} + v_2 x_{2i} + \ldots + v_j x_{ji} \right) = \frac{\sum_{i=1}^{M} u_{mi} y_{mi}}{\sum_{i=1}^{K} v_{ji} x_{ji}}
\]  

Where \( E_i \) is the technical efficiency of farm \( i \)

\( u_m \) is the weight given to output \( m \)

\( y_{mi} \) is the amount of output \( m \) from farm \( i \)

\( v_j \) is the weight given to input \( j \)

\( x_{ji} \) is the amount of input \( j \) on farm \( i \)

Under the restriction that each farm’s efficiency is judged against its individual criteria (individual weighting system), the efficiency of a farm can be obtained as a solution to the following problem: maximise the efficiency of farm \( i \), under the restriction that the efficiency of all farms must be less than or equal to one (farm must be on or below the production possibility frontier). The algebraic model is the fractional model as follows:

\[
\text{Max}_{u,y} \quad E_i = \frac{\sum_{i=1}^{M} u_{mi} y_{mi}}{\sum_{i=1}^{K} v_{ji} x_{ji}}
\]

subject to: \( \frac{\sum_{i=1}^{M} u_{mi} y_{mi}}{\sum_{i=1}^{K} v_{ji} x_{ji}} \leq 1 \) for each farm
The \( u \)'s and \( v \)'s are variables constrained to be greater than or equal to zero (0). The solution of the above model in relation to farm \( i \), gives the value of efficiency of a farm \( i \), and the weights, \( u \) and \( v \), leading to efficiency \( E_i \). However, one problem with this particular ratio formulation is that it has an infinite number of solutions. To solve the model, it is first necessary to convert it to linear form so that the methods of linear programming can be applied. A transformation for fractional programming allows the introduction of a constraint \( \sum v x_i = 1 \), meaning that the sum of all inputs is 1. The model is as follows

\[
\text{Max } u, v \ E_i = \sum_{m}^{M} (u_m y_{mi})
\]

Subject to:

\[
\sum_{i}^{M} (u_{mi} y_{mi}) - \sum_{j}^{K} (v_{ji} x_{ji}) \leq 0, \text{ for each unit I} \quad (3)
\]

\[
\sum_{j}^{K} (v_{ji} x_{ji}) = 1
\]

\[
u_{m}, v_{j} \geq 0
\]

The linear programming problem must be solved \( N \) times, once for each unit in the sample. A value of technical efficiency \( (E) \) is then obtained for each farm.

Using the duality in linear programming, an equivalent envelopment form of this problem can be derived

\[
\text{Min } \theta, \lambda \theta,
\]

Subject to:

\[
y_{i} + Y \lambda \geq 0 \quad (4)
\]

\[
\theta x_{i} - X \lambda \geq 0
\]

\[
\lambda \geq 0
\]
where $\theta$ is a scalar and $\lambda$ is a vector of $N$ constraints. $X$ is an input matrix for $N$ farms and $Y$ is an output matrix for $N$ farms. This envelopment form involves fewer constraints than the multiplier form ($j+m < n+1$), and thus is generally the referred form to solve. The value of $\theta$ obtained is the efficiency score for the $i$-th farm. It satisfies $\theta \leq 1$, with the value of 1 indicating a point on the frontier and hence a technically efficient farm.

4.4.1.1 DEA model for estimation of total technical efficiency

The input oriented DEA model under the assumption of constant returns to scale (CRS) and the DEA model under the assumption of variable returns to scale (VRS) will be used to estimate total technical and pure technical efficiency, respectively, of the sample farms.

We have data on $K$ inputs and $M$ outputs of $N$ farms. $x_i$ is an input vector for $i$th farm and $y_i$ is an output vector for the $i$th farm, $X$ is an input matrix for $N$ farms and $Y$ is an output matrix for $N$ farms.

The input oriented constant return to scale DEA model for calculation of total technical, efficiency is estimated as:

\[
\text{Min } \theta, \lambda \theta,
\]

Subject to

\[
-y_i + Y \lambda \geq 0 \quad \text{(5)}
\]
\[
\theta x_i - X \lambda \geq 0
\]
\[
\lambda \geq 0
\]
where $\theta$ is the total technical efficiency score of $i$th farm and $\lambda$ represents $N \times 1$ constants.

$Y$ is the output matrix for $N$ farms

$X$ is the input matrix for $N$ farms

For the $i$th farm, input and output data are represented by the column vectors $x_i$ and $y_i$, respectively.

### 4.4.1.2 DEA model for estimation of pure technical efficiency

The DEA model with assumption of constant returns to scale is only appropriate when all farms are operating at optimal scale. However, this is not possible in agriculture due to many constraints. The use of the constant returns to scale model when all farms are not operating at optimal scale results in measures of technical efficiencies that are confounded by scale efficiencies. To avoid this problem, the variable returns to scale model is used by adding convexity constraints to constant returns to scale DEA model. It allows the calculation of technical efficiency free from the effects of scale efficiencies. The input oriented variable return to scale DEA model for calculation of pure technical efficiency is estimated as:

$$\text{Min } \theta, \lambda \theta,$$

Subject to

$$-y_j + Y\lambda \geq 0 \quad (6)$$

$$\theta x_i - X\lambda \geq 0$$

$$N/\lambda = 1$$

$$\lambda \geq 0$$
Where:

$\theta$ represents the pure technical efficiency of $i$th farm

$N_1/\lambda = 1$ represents a convexity constraint which ensures that an inefficient firm is only benchmarked against firms of a similar size.

### 4.4.1.3 Estimation of scale efficiency

DEA is a deterministic method used to estimate technical efficiency. It means that it does not explicitly incorporate a random error term and the overall deviation from the frontier is interpreted as inefficiency. The use of DEA provides an opportunity to decompose the total technical efficiency into pure technical and scale efficiency. Pure technical efficiency relates to management practices while scale efficiency relates to the residuals. Thus the results of pure technical and scale efficiency enable better understanding of the nature of technical efficiency of farms belonging to different farm size groups.

In calculating of scale efficiency, the method suggested by Coelli et al. (2005) is applied. Scale efficiency can be obtained residually by dividing the total technical efficiency ($TE_{CRS}$) by pure technical efficiency ($TE_{VRS}$)

$$SE = \frac{TE_{CRS}}{TE_{VRS}}$$

$SE=1$ indicates scale efficiency or constant return to scale (CRS) and $SE < 1$ indicates scale inefficiency. Scale inefficiency arises due to the presence of either increasing returns to scale or decreasing return to scale. DEA also provides means to assess whether a particular firm is
operating in an area of increasing returns to scale or of decreasing returns to scale. This may be
determined by running another DEA model under non increasing returns to scale.

The input-oriented VRS DEA model under non-increasing returns to scale (NIRS) is estimated
as:

$$\text{Min } \theta, \lambda, \theta,$$

Subject to

$$-y_i + Y \lambda \geq 0 \quad (7)$$

$$x_i - X \lambda \geq 0$$

$$N1/ \lambda \leq 1$$

$$\lambda \geq 0$$

The nature of the scale inefficiency for a particular farm, due to increasing returns to scale or due
to decreasing returns to scale, can be determined by seeing whether the non increasing returns to
scale technical efficiency score is equal to the variable return to scale technical efficiency score.
If they are unequal, then increasing returns to scale exist but if they are equal, decreasing returns
to scale exists for the farm.

4.4.1.4 Bootstrapping

Bootstrapping is used to correct for the bias in DEA estimators and establish confidence
intervals. Ignoring the statistical noise in the estimation can lead to biased DEA estimates and
misleading results because all the deviations from the frontier are considered to be inefficient.
Simar and Wilson (1998, 2000) argued that bootstrapping is the most currently feasible method to establish the statistical properties for DEA estimators. This thesis uses the approach of Simar and Wilson (1998, 2000), a smoothed bootstrap procedure, to test the bias in DEA estimators and establish their confidence intervals. Recent advances in DEA literature include using bootstrap methods to establish the confidence intervals of technical efficiency. The bootstrap method in Simar and Wilson (2000) has been applied empirically in several studies of farm efficiency (Brümmer, 2001; Latruffe et al., 2005 and Vu, 2008).

DEA models and the bootstrap approach were estimated in this thesis using the package FEAR developed by Wilson (2009). Using FEAR, the input-based technical efficiencies with constant returns to scale, variable returns to scale and the bias and the confidence interval of the input-based technical efficiency with variable returns to scale were estimated.

### 4.4.1.5 Variable definition

This thesis focuses on diversified crop farming to characterise cropping systems to analyze the impact of determinants on the technical efficiency of farms. The specific objectives of choosing mixed crop farming include (1) measuring the degree of technical efficiency in crop production; (2) assessing whether crop diversification leads to a gain in technical efficiency; and (3) identifying specific characteristics integrated with crop diversification, such as a high ratio of land use that may provide an advantage in crop production, and determining to what extent the factors of land use (farm size, land fragmentation) affect efficiency. The first objective is the
most important because it is used directly in the model to estimate technical efficiencies. This thesis focuses on the production of four groups of crops, namely rice, starchy crops, vegetables, and annual industrial crops. To measure technical efficiencies, the output values of the four groups of crop were aggregated into total output value. This means that, in the model to estimate technical efficiencies, there is only one output variable.

Inputs used in farms to produce rice, starch, vegetables and annual industrial crops include land area used, family labour and crop planting expenditure for seeds, saplings, chemical fertilisers, organic fertilisers, pesticides, herbicides, small non-durable tools, energy, fuel, minor repairs, maintenance, depreciation of fixed assets, rental of assets, machinery, equipment and means of transport, rental of cattle for ploughing, hired laborers, irrigation fees; and other costs such as postage, marketing, production insurance, plant protection, extension and food for working cattle.

Input variables that were in the model include:

Land \((x_1)\) is the total land area cropped for annual cropping in square metres.

Seed \((x_2)\) is expenditure on seeds and saplings used for annual crops in Vietnamese dong (VND).

Fertiliser \((x_3)\) is expenditure on fertilisers, including chemical and organic fertiliser in VND.

Pesticide \((x_4)\) is expenditure on pesticides and herbicides in VND.

Equipments \((x_5)\) is expenditure on total costs of small, non-durable tools, energy, fuel, minor repairs, maintenance, depreciation of fixed assets, rental of asset, machinery, equipment and means of transport and rental of cattle for ploughing, in VND.
Other cost \((x_6)\) is expenditure on hired labourers, irrigation fees and other expenditures in VND.

Family labour \((x_7)\) is the total hours worked by family members on the farm.

The reason that some inputs are aggregated into a single variable is the small input value from many farms in the sample. For example, the majority of observations have “zero” value for irrigation and hired labour.

The input variables are sourced from the VHLSS (2008). The VHLSS (2008) measured the total hours worked for all agricultural production but this thesis focuses on annual crops, therefore, the value of “family labour” variable in this study is measured by the total hours allocated in all agricultural activities, adjusted by the value of annual crop outputs as a proportion of the total value of agricultural products.

4.4.2 Determinants of efficiency

4.4.2.1 Empirical Model

This thesis estimates the determinants of efficiency of farms. The research uses the censored Tobit regression technique to explain variation in efficiency across farms, where the dependent variable is the pure technical efficiency. The farm-specific explanatory variables are comprised of dichotomous and continuous variables. These independent variables are farm size, land intensity, number of plots, family labour, ratio of land to family labour (land/family labour in
square meters/hour), characteristics of farm head (education and age), ratio of non-farm income in total income, and crop diversification (Herfindahl index, Ogive index).

Total technical efficiency has two components: *pure technical* and *scale efficiency*. Pure technical efficiency relates to management practices while scale efficiency relates to the residuals. Therefore, only pure technical efficiency was chosen as the independent variable in the analysis of factors explaining the technical efficiency differentials among the sample farms (See section 2.3.2).

There are at least two reasons to use a Tobit regression analysis (Tobin, 1958) to test the hypotheses in this thesis. First, the value of the dependent variable—technical efficiency—ranges between zero and one. The rationale behind using the Tobit model is that there are a number of farms for which efficiency could be “1” and the bounded nature of efficiency between “0” and “1”. That is, the distribution of efficiency is censored from above at unity. Second, in a Tobit regression, the independent variable is not assumed to be normally distributed. Therefore, the inclusion of continuous and binary explanatory variables in a model is possible (Haji, 2006). Based on the above discussion, in this thesis, the Tobit regression model was used to test the hypotheses.

An analysis using four Tobit regression models were conducted for this thesis. The first model includes farm size (the output value), number of plots, land intensity, family labour size, ratio of
land to family labour, education of farm head, age of farm head, share of off-farm income and Herfindahl index variables. Model 1 is given by the following function:

Model 1

\[ E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \beta_7 Z_{7i} + \beta_8 Z_{8i} + \beta_9 Z_{9i} + \beta_{10} Z_{10i} + \mu_i \]

if \( E^* < 1 \)

\[ E_i = 1 \quad \text{if} \quad E^* \geq 1 \]  

(8)

Where

\( E_i \) is an efficiency measure representing pure technical efficiency of the \( i \)th farm. The coefficient \( \beta_0 \) is the intercept term, and \( \beta_j (j = 1, \ldots, m) \) represents the coefficients associated with the corresponding independent variables, and \( \mu_i \) is an error term. The coefficient estimates are obtained by regression that involves maximizing a log-likelihood function.

\( Z_{1i} \) is farm size (the output value) of farm \( i \)

\( Z_{2i} \) is number of plots of farm \( i \)

\( Z_{3i} \) is the ratio of land cropped of farm \( i \)

\( Z_{4i} \) is family labor size of farm \( i \)

\( Z_{5i} \) is ratio of land to family labour of farm \( i \)

\( Z_{6i} \) is education level defined as 1 if farm head completed one class in secondary level and 0 if otherwise.

\( Z_{7i} \) is education level defined as 1 if farm head completed one class in high school level or more and 0 if otherwise.

\( Z_{8i} \) is the age of farm head
\( Z_{oi} \) is share of off-farm income of farm \( i \)

\( Z_{10i} \) is the degree of Herfindahl index of farm \( i \)

The second model is similar to Model 1 but with another measure of crop diversification (Ogive index), the second model is given by in the following function:

**Model 2**

\[
E_i = E_i^* = \beta_0 + \beta_{1i} Z_{2i} + \beta_{2i} Z_{3i} + \beta_{3i} Z_{4i} + \beta_{4i} Z_{5i} + \beta_{5i} Z_{6i} + \beta_{6i} Z_{7i} + \beta_{7i} Z_{8i} + \beta_{8i} Z_{9i} + \beta_{9i} Z_{10i} + \mu_i
\]

if \( E^* < 1 \)

\[
E_i = 1 \quad \text{if} \quad E^* \geq 1
\]

Where

\( Z_{2i} \) to \( Z_{9i} \) are as for model 1

\( Z_{10i} \) is the degree of Ogive index of farm \( i \)

The third model is similar to Model 1 but with another measure of farm size variable (land area), the third model is given by in the following function:

**Model 3**

\[
E_i = E_i^* = \beta_0 + \beta_{1i} Z_{2i} + \beta_{2i} Z_{3i} + \beta_{3i} Z_{4i} + \beta_{4i} Z_{5i} + \beta_{5i} Z_{6i} + \beta_{6i} Z_{7i} + \beta_{7i} Z_{8i} + \beta_{8i} Z_{9i} + \beta_{9i} Z_{10i} + \mu_i
\]

if \( E^* < 1 \)

\[
E_i = 1 \quad \text{if} \quad E^* \geq 1
\]

Where

84
\( Z_{1i} \) is land area of farm \( i \)

\( Z_{10i} \) is the Herfindahl index of farm \( i \)

The fourth model is similar to Model 3 with another measure of the crop diversification variable (Ogive index), the fourth model is given by in the following function:

Model 4

\[
E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \beta_7 Z_{7i} + \beta_8 Z_{8i} + \beta_9 Z_{9i} + \beta_{10} Z_{10i} + \mu_i
\]

if \( E^* < 1 \) \hspace{1cm} (11)

\[
E_i = 1 \quad \text{if} \quad E^* \geq 1
\]

Where

\( Z_{1i} \) to \( Z_{9i} \) are as for model 3

\( Z_{10i} \) is the Ogive index of farm \( i \)

4.4.2.2 Goodness of fit

The Tobit regression does not have an equivalent to the R-squared that is found in ordinary least squares (OLS) regression. The Tobit models are maximum likelihood estimated arrived at through an iterative process. They are not calculated to minimise variance, so the OLS approach to goodness-of-fit does not apply. There are a wide variety of pseudo R-square statistics developed to evaluate the goodness-of-fit of Tobit models. These look like R-squared in the
sense that they are on a similar scale, ranging from zero (0) to 1, with higher values indicating better model fit, but they cannot be interpreted as one would interpret an OLS R-squared. In this study, Stata (a software package) was used to estimate the Tobit regression models and McFadden’s pseudo R-squared is utilised which is and it is calculated as follows:

\[ R^2 = 1 - \left[ \ln \hat{L} (M_{full}) / \ln \hat{L} (M_{intercept}) \right] \]

The ratio of the log likelihoods suggests the level of improvement of one model. If comparing two models on the same data, the likelihoods are compared to judge which of the models - Model 1, Model 2, Model 3 and Model 4, best fit the data.

### 4.4.2.3 Statistical significance

To test the significance of the effect of the independent variables on the Tobit regression model, the \(t\) and \(p\) values were estimated. The using of \(t\)-test in this study is to test the null hypothesis that a particular predictor’s regression coefficient is zero, given that the rest of the predictors are in the model. For a given alpha level (0.05 or 0.01), the \(p\)-value would be computed to determine whether or not the null hypothesis can be rejected. If \(p\)-value is less than alpha level, then the null hypothesis can be rejected and the parameter estimate is considered statistically significant at that alpha level.
4.5 Summary

This chapter provides details of the research design used in the examination of main points in this thesis. The research design includes data selection procedures and how the models are applied to the data. Data Envelopment Analysis was used to estimate technical efficiencies. The Tobit regression models involve analysis where the dependent variable estimated in DEA is the pure technical efficiency of sampled data. Four Tobit models were used to predict which determinants of farm size, land fragmentation, family labour size, ratio of land to family labour, education of farms head, ratio of off-farm income and crop diversification could impact on technical efficiency of farms.
Chapter 5 PRESENTATION OF RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the empirical results from the estimation of technical efficiency and scale efficiency. The chapter also identifies determinants of pure technical efficiency. The efficiency estimations were conducted by Data Envelopment Analysis and the examination of determinants was carried out using Tobit regression analysis. This thesis tests whether farm size, land fragmentation, land use intensity, family labour size, ratio of land to labour, age of farm head, education of farm head, ratio of off-farm income and crop diversification are significant determinants of technical efficiency.

The rest of this chapter is organised as follows. Section 5.2 presents a descriptive statistics of input and output variables used to estimate technical efficiency. Summary statistics of variables used in the Tobit regression are also presented in this section. Section 5.3 reports the results of technical efficiency estimation. Section 5.4 reports the results from Tobit regression estimations. Section 5.5 discusses the results. Section 5.6 summarises the results of the study.

5.2 Descriptive Statistics

A summary of the values of key variables included in DEA models and Tobit regression model is given in Table 5.1 and Table 5.3.
Table 5.1 provides a summary of the characteristics of the sampled farms. The average family size is four people and there is an average of two family members working on the farm. Table 5.1 indicates population pressure on the land with low levels of land per capita. The average land per family member is 771 square metres. In terms of farm head, it is observed that 91 per cent of the farm heads completed primary school education; 67 per cent of farm heads completed secondary education and only 13 per cent of them completed high school.

Farms in the sample differ in size, intensity of input use and output. Table 5.1 gives the descriptive statistics of the inputs and output that are defined in Chapter 4. Table 5.1 shows that the sampled farms are quite small, with an average size of only half of a hectare. The average cultivated land area used was 5,098 square metres, with a minimum area of 1,010 square metres and maximum area of 24,280 square metres.

The farms depend on purchased inputs. The average value of seed used per farm was 384,000 Vietnam dong (VND) and ranged between 24,000 and 2,424,000 VND. The average cost of fertiliser per farm was 1,825,000 VND ranging between 191,000 and 11,040,000 VND. The average value of pesticides used per farm was 407,000 VND and ranged from 0 to 2,611,000 VND. The average cost of equipment per farm was 684,000 VND, which up to 4,544,000 VND. The mean of other costs was 384,000 VND per farm. The average time that members of a farm worked was 1,438 hours. The average value of annual crops per farm was 11,253,000 VND with minimum value of 2,292,000 VND and maximum value of 40,797,000 VND. More of the distribution of inputs and scatterplots are shown in Figure A-1 to Figure A-21 in Appendix.
Table 5.1: Summary statistics for the sample farms

<table>
<thead>
<tr>
<th>Inputs/Output</th>
<th>Units</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area cropped</td>
<td>square metres</td>
<td>1,010</td>
<td>24,280</td>
<td>5,098</td>
<td>3,331</td>
</tr>
<tr>
<td>Seed</td>
<td>1000 VND</td>
<td>24</td>
<td>2,424</td>
<td>384</td>
<td>295</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>1000 VND</td>
<td>191</td>
<td>11,040</td>
<td>1,825</td>
<td>1,329</td>
</tr>
<tr>
<td>Pesticide</td>
<td>1000 VND</td>
<td>0</td>
<td>2,611</td>
<td>407</td>
<td>349</td>
</tr>
<tr>
<td>Equipment</td>
<td>1000 VND</td>
<td>0</td>
<td>4,544</td>
<td>684</td>
<td>514</td>
</tr>
<tr>
<td>Other cost</td>
<td>1000 VND</td>
<td>0</td>
<td>3,384</td>
<td>384</td>
<td>431</td>
</tr>
<tr>
<td>Family labour hours for farming</td>
<td>hours for farming</td>
<td>117</td>
<td>6,499</td>
<td>1,438</td>
<td>1,029</td>
</tr>
<tr>
<td>Output (the total value of crops)</td>
<td>1000 VND</td>
<td>2,292</td>
<td>40,797</td>
<td>11,253</td>
<td>6,813</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farm household characteristics</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Family size</td>
<td>number</td>
<td>1</td>
<td>9</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Family labour size</td>
<td>number</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Land per capita</td>
<td>square metres/person</td>
<td>130</td>
<td>4,875</td>
<td>771</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm heads complete primary education</td>
<td>percentage</td>
<td></td>
<td></td>
<td></td>
<td>91</td>
</tr>
<tr>
<td>Farm heads complete secondary education</td>
<td>percentage</td>
<td></td>
<td></td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>Farm heads complete high education</td>
<td>percentage</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2008

Table 5.2 shows that fertiliser accounted for the highest proportion of total input cost (ignoring labour and land) among the purchased inputs. It accounted for approximately 49 per cent of total cost, followed by equipment at 19 per cent. Seed, pesticides and others shared around 10 per cent each.
Table 5.2: Percentage share of total cost contributed by each input

<table>
<thead>
<tr>
<th>Input</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>1</td>
<td>43</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>17</td>
<td>90</td>
<td>49</td>
<td>12</td>
</tr>
<tr>
<td>Pesticides</td>
<td>0</td>
<td>29</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Equipment</td>
<td>0</td>
<td>53</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>43</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Based on VHLSS 2008

The farm-specific variables are also shown in Table 5.3. The average age of farm head was 49. The average land area managed was 2,800 square metres. The average number of plots per farm was 3.4 and ranged between 1 and 12. The average ratio of land intensity was 2 and ranged from 0.4 to 3.2. The average ratio of off-farm income was 0.14 to 0.97. Herfindalh index ranged from 0.29 to 1, with the mean value at 0.72. The average Ogive index was 1.63 with a minimum value of 0.23 and a maximum value of 3.
Table 5.3: Summary statistics of determinant variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Dummy variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Percentage with dummy=1</td>
</tr>
<tr>
<td>Land area managed (1000m^2)</td>
<td>2.8</td>
<td>2.7</td>
<td>0.5</td>
<td>20.9</td>
<td></td>
</tr>
<tr>
<td>Total output value (million VND)</td>
<td>11.3</td>
<td>6.8</td>
<td>2.3</td>
<td>40.8</td>
<td></td>
</tr>
<tr>
<td>Number of plots (number)</td>
<td>3.4</td>
<td>1.8</td>
<td>1.0</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>Land intensity (ratio)</td>
<td>2.0</td>
<td>0.5</td>
<td>0.4</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Family labour size (number)</td>
<td>2.3</td>
<td>1.0</td>
<td>1.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Land/Family labour (square metres/hour)</td>
<td>3</td>
<td>2</td>
<td>0.3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>0</td>
<td>1</td>
<td>20</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>0</td>
<td>1</td>
<td>64</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>0</td>
<td>1</td>
<td>16</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Age of farm head (number)</td>
<td>49</td>
<td>10</td>
<td>25</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>Ratio of off-farm income</td>
<td>0.14</td>
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</table>

Source: Based on VHLSS (2008)

Table 5.4 shows the correlations between independent variables in the regression models. The correlations were investigated using Pearson product-moment correlation coefficient. There was a medium, negative correlation between land area and land use intensity with smaller land area associated with higher levels of land use intensity. It seems that small farms may use land more intensively than larger farms. The strength of correlation between farm size and fragmentation...
and between farm size and crop diversification is weak. This supports their use in the model.

There is a strong, positive relationship between two variables of crop diversification (Ogive index and Herfindahl index), which indicates that they can be used in place of each other.
Table 5.4: Pearson Correlations

<table>
<thead>
<tr>
<th></th>
<th>Land area</th>
<th>No of plot</th>
<th>Land intensity</th>
<th>Herfindahl index</th>
<th>Ogive index</th>
<th>Number of family Labour</th>
<th>Land/Family Labour</th>
<th>Age of farm head</th>
<th>Year of schooling</th>
<th>Ratio of Off-farm income</th>
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<td>-.192***</td>
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Raw Text:

Table 5.4: Pearson Correlations

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<th>Land intensity</th>
<th>Herfindahl index</th>
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<th>Ratio of Off-farm income</th>
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</tr>
</tbody>
</table>

*** Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).
* Correlation is significant at the 0.10 level (2-tailed).
5.3 Technical efficiency estimation results

The results derived from Data Envelopment Analysis models are presented in Table 5.5. It is evident from the results that total technical efficiency indices ($TE_{CRS}$) range from 0.33 to 1.0, with a mean of 0.80. The mean pure technical efficiency ($TE_{VRS}$) of the sample farms is 0.83, with a low of 0.43 and a high of 1.00. According to the theory of technical efficiency, a farm can reduce its inputs by $\frac{1}{TE_{VRS}} - 1$ without changing the level of its output (Vu, 2008). The results imply that if the average sample farm operated at full efficiency level it could reduce, on average, its input use by 20.5 per cent $\frac{1}{0.83} - 1$ and still produce the same level of outputs.

<table>
<thead>
<tr>
<th></th>
<th>$TE_{CRS}$</th>
<th>$TE_{VRS}$</th>
<th>Bias-corrected TE</th>
<th>Lower bound</th>
<th>Higher bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.80</td>
<td>0.83</td>
<td>0.76</td>
<td>0.70</td>
<td>0.83</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>0.15</td>
<td>0.14</td>
<td>0.12</td>
<td>0.10</td>
<td>0.14</td>
</tr>
<tr>
<td>Min</td>
<td>0.33</td>
<td>0.43</td>
<td>0.39</td>
<td>0.35</td>
<td>0.42</td>
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<tr>
<td>Max</td>
<td>1.00</td>
<td>1.00</td>
<td>0.95</td>
<td>0.92</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Note: Lower and Upper bound apply to the Bias corrected TE

Using Data Envelopment Analysis to estimate technical efficiency may have biases in efficiency scores because in the model, the true production frontier is unknown and the points on the observed production function may be inefficient in the presence of the true production frontier. Using bootstrap method in Wilson (2009a, b), bias-corrected TE scores were estimated. As Table 5.5 shows, the mean of bias-corrected TE is 0.76 which is lower than the initial TE score. This
means that the amount of input saving is 31.6 per cent \( \frac{1}{0.76} - 1 \) after correcting for the bias.

In the same way, a farm can reduce their inputs on average from 20.5 per cent to 42.9 per cent with a 95 per cent confidence interval. It implies that the potential amount of inputs that can be saved is considerable.

### Table 5.6: Distribution of technical efficiency of sample

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TE (CRS)</td>
</tr>
<tr>
<td>0.10-0.30</td>
<td>0</td>
</tr>
<tr>
<td>0.31-0.40</td>
<td>2</td>
</tr>
<tr>
<td>0.41-0.50</td>
<td>2</td>
</tr>
<tr>
<td>0.51-0.60</td>
<td>39</td>
</tr>
<tr>
<td>0.61-0.70</td>
<td>77</td>
</tr>
<tr>
<td>0.71-0.80</td>
<td>92</td>
</tr>
<tr>
<td>0.81-0.90</td>
<td>79</td>
</tr>
<tr>
<td>0.91-0.99</td>
<td>51</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>423</strong></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>0.80</strong></td>
</tr>
<tr>
<td><strong>Std. deviation</strong></td>
<td><strong>0.15</strong></td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td><strong>0.33</strong></td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>

Table 5.6 shows more scale efficiency. The mean of scale efficiency is 0.95 ranging from 0.63 to 1. This means the decomposition of the total technical inefficiency measure produced estimates of 17 per cent pure technical inefficiency and 5 per cent scale inefficiency. By eliminating scale inefficiency the farms can increase their average technical efficiency level from 80 to 83 per cent.
Frequency distributions of total technical efficiency, pure technical efficiency, scale efficiency of the sample farms are presented in Table 5.6 and Figures 5.1 to 5.3. It is evident that 31.2 per cent of farms have total technical efficiency between 0.91 and 1.0, 18.7 per cent of farms have efficiency ranging from 0.81 to 0.90. The figures also show that, 21.7 per cent of farms have efficiency between 0.71 and 0.80; 18.2 per cent of farms have total technical efficiency between 0.61 and 0.70; and 10.2 per cent of farms have efficiency less than 0.61.

**Figure 5.1: Frequency distribution of total technical efficiency**
It can be observed from Figure 5.2 that the pure technical efficiency of the majority of the sample farms falls within the range of 0.81 and 1.0. Out of the sample, 40.4 per cent of farms have pure technical efficiency greater than 0.90, 17.7 per cent of farms have efficiency between 0.81 and 0.90, 19.6 per cent of farms have efficiency between 0.71 and 0.80 and 22.2 per cent of farms have pure technical efficiency less than 0.71.
The results of this study indicate that the mean scale efficiency of the sample farms is 0.95, with the minimum of 0.63 and a maximum of 1.0. As shown in Figure 5.3 that depicts the scale efficiency, most of the sample farms to fall between 0.91 and 1.0. 37.6 per cent of farms have optimal scale efficiency. 47.3 per cent of farms have scale efficiency between 0.91-0.99. 12.8 per cent of farms have scale efficiency between 0.81-0.90; 1.6 per cent of farms have scale efficiency between 0.71-0.80; and only 0.7 per cent of farms have scale efficiency less than 0.70. This shows that most of the farms are close to the efficient level.
Table 5.7: Summary of returns to scale results (n=423)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Number of farms</th>
<th>Percentage</th>
<th>Mean (1000 VN Dong)</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS</td>
<td>159</td>
<td>38</td>
<td>13,424</td>
<td>2,292</td>
<td>40,797</td>
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<tr>
<td>IRS</td>
<td>204</td>
<td>48</td>
<td>7,534</td>
<td>2,429</td>
<td>18,629</td>
</tr>
<tr>
<td>DRS</td>
<td>60</td>
<td>14</td>
<td>18,149</td>
<td>3,202</td>
<td>38,828</td>
</tr>
</tbody>
</table>

CRS: Constant return to scale; IRS: increasing return to scale; DRS: Decreasing return to scale.

The source of scale inefficiency and their corresponding output levels are reported in Table 5.7. The results reported in this table are the percentages of farms which have increasing returns to scale (IRS), decreasing returns to scale (DRS) and constant returns to scale. The results indicate that in the sample, 37.60 per cent of farms are achieving scale efficiency while the remaining 62.40 per cent are scale inefficient. Among scale inefficient farms, 204 farms (representing 77.27 per cent) have increasing returns to scale and 60 farms (representing 22.73 per cent) have decreasing returns to scale. These results are consistent with the second hypothesis that increasing returns to scale outweighs decreasing returns to scale, suggesting a large number of farms should increase their scale to gain scale efficiency.

A one-way between-groups analysis of variance can provide insights on how size affects efficiency levels. ANOVA was conducted to further explore the impact of farm size on levels of efficiency. Subjects were divided into three groups according to land area (Group 1: less than
2,000 square meter; Group 2: between 2,000 and 5,000 square meter; Group 3: more than 5,000 square meter) and according to total output value (Group 1: less than 5,000 thousand VND; Group 2: 5,000 to 15,000 thousand VND; Group 3: more than 15,000 thousand VND). The results are presented in Table 5.8. They suggest that farm size had a statistically significant impact on efficiency. Especially, the differences in scale efficiency between the three size groups (in term of land area and output value) are highly significant.

Table 5.8: The impact of size on efficiency: ANOVA analysis, F-statistics

<table>
<thead>
<tr>
<th>Size</th>
<th>Total technical efficiency</th>
<th>Pure technical efficiency</th>
<th>Scale efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area</td>
<td>2.87*</td>
<td>3.76**</td>
<td>24.14***</td>
</tr>
<tr>
<td>Output value</td>
<td>13.90***</td>
<td>10.61***</td>
<td>91.68***</td>
</tr>
</tbody>
</table>

*** Significant at 0.01 level; ** Significant at 0.05 level; * significant at 0.10 level

Table 5.9 shows the scale efficiency scores for three size intervals in land area and output value, respectively. The smallest farms were the least efficient for both land area and output value. Moreover, Bonferroni, Scheffe and Sidak multiple comparison tests were conducted to examine the differences between each pair of means. The differences of scale efficiency between group 1 and Group 2 and between Group 1 and Group 3 are significant, while between Group 2 and Group 3 are not significant for both land area and output value. These results suggest farm size have a positive impact on scale efficiency.
Table 5.9: Scale efficiency according to farm size

<table>
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<th>Mean SE</th>
<th>Std. Dev.</th>
<th>Frequency</th>
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<tr>
<td>Group 1</td>
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<td>Group 3</td>
<td>0.97</td>
<td>0.05</td>
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<td>0.04</td>
<td>267</td>
</tr>
<tr>
<td>Group 3</td>
<td>0.98</td>
<td>0.04</td>
<td>93</td>
</tr>
</tbody>
</table>

In summary, the pure technical efficiency of the sample is 0.83. This estimated mean level of technical efficiency is higher than other estimates in the literature on technical efficiency for producing only rice in Vietnam. For example, Vu (2008) estimated the technical efficiency of rice production in all regions of Vietnam to be 0.78 while Huynh and Yabe (2011) estimated it to be 0.81. This suggests higher technical efficiency in diversified crops. The mean of scale efficiency among sampled farms is 0.95. Assessing the scale efficiency results, it can be concluded that scale inefficiency is not the major source of total farm inefficiency. This result is consistent with literature on the scale efficiency of rice-based farms indicating that scale efficiency is larger than pure technical efficiency (as can be seen in Table 5.10). Therefore, the determinants of technical efficiency are explored using pure technical efficiency. The next section presents the estimates of the determinants of pure technical efficiency.
Table 5.10: Comparison: return to scale summary

<table>
<thead>
<tr>
<th>References</th>
<th>Country</th>
<th>DRS</th>
<th>CRS</th>
<th>IRS</th>
<th>TE pure</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>The present thesis</td>
<td>Vietnam</td>
<td>14</td>
<td>48</td>
<td>38</td>
<td>0.83</td>
<td>0.95</td>
</tr>
<tr>
<td>Vu (2008)</td>
<td>Vietnam</td>
<td>18</td>
<td>23</td>
<td>59</td>
<td>0.78</td>
<td>0.89</td>
</tr>
<tr>
<td>Krasachat (2004)</td>
<td>Thailand</td>
<td>19</td>
<td>32</td>
<td>49</td>
<td>0.74</td>
<td>0.96</td>
</tr>
<tr>
<td>Wadud and White (2000)</td>
<td>Bangladesh</td>
<td>63</td>
<td>16</td>
<td>21</td>
<td>0.86 and 0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Coelli et al. (2002)</td>
<td>Bangladesh</td>
<td>58.06</td>
<td>10.90</td>
<td>31.04</td>
<td>0.66</td>
<td>0.93</td>
</tr>
<tr>
<td>Brádik (2006)</td>
<td>Indonesia</td>
<td>66</td>
<td>12</td>
<td>22</td>
<td>0.60 and 0.77</td>
<td>0.90</td>
</tr>
<tr>
<td>Javed (2009)</td>
<td>Pakistan</td>
<td>0</td>
<td>17</td>
<td>83</td>
<td>0.87</td>
<td>0.79</td>
</tr>
<tr>
<td>Small size</td>
<td>Pakistan</td>
<td>10</td>
<td>17</td>
<td>73</td>
<td>0.79</td>
<td>0.94</td>
</tr>
<tr>
<td>medium</td>
<td>Pakistan</td>
<td>42</td>
<td>24</td>
<td>34</td>
<td>0.81</td>
<td>0.94</td>
</tr>
<tr>
<td>large</td>
<td>Nepal</td>
<td>42</td>
<td>11</td>
<td>47</td>
<td>0.82</td>
<td>0.93</td>
</tr>
<tr>
<td>Dhhungana (2004)</td>
<td>Nepal</td>
<td>42</td>
<td>11</td>
<td>47</td>
<td>0.82</td>
<td>0.93</td>
</tr>
</tbody>
</table>

5.4 Tobit regression results

Results from the analysis of Tobit models are presented in Table 5.11. The independent variable tested in hypothesis on the impact of crop diversification is the Herfindahl index in Model 1 and Model 3, and the Ogive index in Model 2 and Model 4. The independent variable tested in hypothesis on the impact of farm size is the output value in Model 1 and Model 2, and land area in Model 3 and Model 4. The table reports the parameter estimates and their statistical significance. Table 5.11 also reports the results of testing the goodness of fit using the log likelihood ratio and Pseudo R2.
In general, the sign and strength of coefficients are stable across models. In Table 5.11, the Likelihood Ratios (LR) Chi-square tests are 72, 71, 50 and 51 in Model 1, Model 2, Model 3 and Model 4, respectively. It is significant at the 1 per cent level of significance. It means that at least one of the predictors’ regression coefficients is not equal to zero in the four models. The log likelihood is -13.443, -13.886, -24.277 and -24.124 in Model 1, Model 2, Model 3 and Model 4, respectively. Moreover, the Pseudo R2 is 0.73 for Model 1; 0.72 for Model 2; 0.50 for Model 3 and 0.51 for Model 4. These results show that the models that use the output value have a stronger relationship between the dependent and independent variables and suggest that the variables used in these models (Model 1 and Model 2) are more useful in explaining the determinants of technical efficiency.
Table 5.11: Determinants of technical efficiency: estimates from Tobit models

<table>
<thead>
<tr>
<th>Variables name</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.031 ***</td>
<td>0.916 ***</td>
<td>1.037 ***</td>
<td>1.003 ***</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.115)</td>
<td>(0.092)</td>
<td>(0.084)</td>
</tr>
<tr>
<td>Farm size (Value of output)</td>
<td>0.008 ***</td>
<td>0.007 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm size (land area)</td>
<td></td>
<td></td>
<td>0.004</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Fragmentation</td>
<td>-0.014 ***</td>
<td>-0.014 **</td>
<td>-0.011*</td>
<td>-0.010 *</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Land use intensity</td>
<td>-0.027</td>
<td>-0.023</td>
<td>-0.011</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.022)</td>
<td>(0.022)</td>
</tr>
<tr>
<td>Family labour size</td>
<td>-0.023 **</td>
<td>-0.022**</td>
<td>-0.012</td>
<td>-0.012</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.011)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Ratio of land and family labour</td>
<td>0.020***</td>
<td>0.020***</td>
<td>0.024****</td>
<td>0.024 ***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>Secondary</td>
<td>-0.084***</td>
<td>-0.089***</td>
<td>-0.080</td>
<td>-0.081</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>High school</td>
<td>-0.089***</td>
<td>-0.089***</td>
<td>-0.084</td>
<td>-0.085</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.031)</td>
<td>(0.032)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>Age of farm head</td>
<td>-0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>-0.000</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Ratio of non farm</td>
<td>0.081 **</td>
<td>0.080 **</td>
<td>0.062</td>
<td>0.063</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>income</td>
<td>(0.037)</td>
<td>(0.037)</td>
<td>(0.038)</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Herfindahl index</td>
<td>-0.112 **</td>
<td></td>
<td>-0.106 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td></td>
<td>(0.047)</td>
<td></td>
</tr>
<tr>
<td>Ogive index</td>
<td>-0.027 **</td>
<td></td>
<td>-0.028 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td></td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>LR chi 2(10)</td>
<td>72.000</td>
<td>71.120</td>
<td>50.340</td>
<td>50.640</td>
</tr>
<tr>
<td>Prob &gt;chi2</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.728</td>
<td>0.719</td>
<td>0.509</td>
<td>0.512</td>
</tr>
</tbody>
</table>

*** Significant at 0.01 level; ** Significant at 0.05 level; * significant at 0.10 level
Figures in parentheses are standard errors

5.5 Discussion of Results

In this section, the results are discussed in nine subsections. The estimated determinants of technical efficiency among farm households in the northern region of Vietnam were tested against the expectations from the literature survey.

5.5.1 Farm size

The results from Models 1 and 2 presented in Table 5.11 confirm Hypothesis 3 that there is a significantly positive relationship between farm size (total output value) and technical efficiency. The coefficient on farm size is positive and significant at the 1 per cent level, thereby indicating that the larger the farm size the greater technical efficiency scores farms have.
Models 3 and 4 also test Hypothesis 3 but by examining the relationship between land area and technical efficiency of farms. However, the results are not consistent with the hypothesis as the coefficient for land area, which represents the total annual land use area managed by farms, is positive but not significant at any level in these two models. An explanation for the lack of significant impact of farm size by land area on technical efficiency may be due to the small variation in farm size by land in the sample. 97 per cent of sampled farms have farm area of less than 1 hectare. Thus, the majority of farms households in the sample are small-scale farms.

These findings on the coefficient for land area suggest that land area is not an appropriate measure of farm size. Lund (1983) stated that there was no generally accepted measure of farm size in the economics literature to guide the choice in the specifically agricultural context. Various measures of farm size (such as measures of outputs or inputs, sales or turnover, number of employees or value of fixed capital, and of the incomes) are used in different contexts. Lund et al. (1998) argued that land area could be a poor economic measure of farm size since land would be so variable in its agricultural attributes and farms of different types could require vastly different areas of land for the same value of output. In the context of diversified crops the output values among crops are variable in a given land area, thereby land area may not be a good measure of farm size.

The finding that farm size enhances technical efficiency is consistent with expectation and the positive effect of farm size on productivity is found in many other Vietnamese studies (see for instance, Akram-Lodhi, 2001; Rio and Shively, 2005). Vu (2008) in a study of efficiency of rice
farming households in Vietnam, found that farm size, measured by total farm output value, had substantial benefits for technical efficiency improvement. Similarly, Rio and Shively (2005) established that smaller coffee farms had lower technical efficiency in two districts of Dac Lac province of Vietnam. In general, the studies of the relationship between farm size and technical efficiency in Vietnam do not support the inverse relation theory.

The findings are contrary to the theoretical perspective of an inverse relationship that is based on the argument that smaller farm size is advantageous. However, Akram-Iodhi (2001, 2005) suggested that inverse relationship between size of farm and productivity could not be substantiated because a process of class differentiation might be underway in Vietnam, with the apparent emergence of a stratum of rich farms with relatively larger landholdings and stock of capital. This changes the choice of farming techniques benefiting larger farms. This is due to an enhanced ability to access marked-production techniques such as the credit market. This suggests the inverse relationship between farm size and productivity generally does not exist in market oriented agriculture.

5.5.2 Land Fragmentation

The proposition in Hypothesis 4 is that there is a negative relationship between the total number of plots per farm and technical efficiency. The results in Table 5.11 report that the coefficient on number of plots, which denotes the number of plots in the annual land use, is negative and significant in Models 1, 2, 3 and 4. This suggests that farms with more plots will have a lower
technical efficiency consistent with Hypothesis 4. This indicates that high degree of land fragmentation has a negative impact on technical efficiency of farms. The results are consistent with Wadud and White, (2000); Brázdik (2006) and Rahman and Rahman (2008) who also found that increasing land fragmentation reduced technical efficiency of rice farms.

In a study conducted in the northern part of Vietnam, Pham (2007) found that the number of plots did not have an impact on productivity as reflected in the equivalent rice yield. However, Pham (2007) noted that there was a negative correlation between fragmentation and the revenue from a mixed cropping system of rice-based production. The results in this thesis confirm that fragmentation adversely affects technical efficiency in a mixed cropping system in Vietnam. This gives an indication that the impact of land fragmentation may depend on the cropping system. In a subsistence-oriented cropping system, land fragmentation can have a rather positive impact on production due to the application of inputs use intensity in small parcels (Niroula and Thapa, 2007). On the other hand, in a market-oriented crop system fragmentation can contribute to weakening economic competitiveness of farms through increased cost of inputs (Niroula and Thapa, 2005). Therefore, the disadvantages of fragmented plots may outweigh their benefits in a commercialised economy.

5.5.3 Land intensity

The findings presented in Table 5.11 are not consistent with Hypothesis 5 in Model 1, 2, 3 and 4. The coefficient for land intensity, which is the ratio of total land area used for cropping and farm...
area available for annual cropping, is inconsistent with Hypothesis 5. The estimated coefficient for land use intensity is not statistically significant and therefore the null hypothesis is not disproved. The farms in this thesis have already achieved these sources of technical efficiency so this factor may not have a large impact. The findings imply land intensity is not a determinant of technical efficiency.

5.5.4 Family labour size

The results shown in Table 5.11 are consistent with Hypothesis 6 that the number of family members working on the farm is negatively associated with the technical efficiency of farms. The coefficient on family labour size is negative and statistically significant in Models 1 and 2.

In northern part of Vietnam where the majority of farms are very small, family labour may put pressure on farming. The finding is consistent with other studies in developing countries which highlight the disadvantages of surplus labour in these economies (See for instance, Coelli et al., 2002; Haji, 2006; Bozoglu and Ceyhan, 2006).

In the literature on Vietnam, Tran (2007) also established a negative relationship between family labour and technical efficiency scores of coffee farms. This finding was attributed to overuse of inputs including family labor in coffee production.
5.5.5 Ratio of land to family labour

The results presented in Table 5.11 are consistent with Hypothesis 7 which stipulates a positive association between the ratio of land to family labour used on the farm and technical efficiency. The coefficient on ratio of land to family labour, which is measured by the ratio of land area to the total number of hours devoted to farming by family members, is positive and highly significant at the 1 per cent level in Model 1, 2, 3 and 4.

These results indicate that land area is a significant correlate that affects technical efficiency when it is combined with family labor. As noted earlier, the coefficient on land area is not statistically significant when it enters the regression on its own.

The results in this thesis have a similar result to that of Vu (2008) in a study of rice farming in Vietnam. Vu (2008) found that the land/labour ratio had a significant positive impact on technical efficiency in DEA models. The empirical findings in this present study and in Vu (2008) match with the Vietnamese farm’s characteristics concerning which farms have pressure on the land from abundant agricultural labour. Akram-Lodhi (2005) argued that controlling the size and numbers of agricultural labour is essential to increase farming productivity in the case of Vietnam.
5.5.6 Education of farm head

The results in Table 5.11 are not consistent with the expectation presented in Hypothesis 8. This hypothesis postulates a positive relationship between educational attainment of farm heads at the secondary and high school levels and technical efficiency. However, the findings in this study reveal that there is a negative and significant association between education of farm heads and technical efficiency. Farms headed by household heads who have completed secondary or high school education are less technically efficient than those headed by heads who have primary education or less.

The unexpected result of a negative impact of education on technical efficiency is contrary to the bulk of literature but reinforces the findings by Fleming and Lummani (2001) and Hasnah et al. (2004), who found a significantly negative impact of education on technical efficiency in Papua New Guinea and Indonesia, respectively. Kalirajan and Shand (1985) argued that farmers’ schooling and their productive capacity need not be significantly related under all circumstances. For example, in a technologically advanced area, where there are no serious production constraints, such as input availability, the schooling of farmers is not necessarily an important factor for efficiency. Kalirajan and Shand (1985) identified informal education as more significant for the productive efficiency of smallholders than formal education at levels beyond primary education. This may be indicative that a high level of education does not necessarily contribute to the ability of farmers to access useful information or knowledge for cropping. This implication is also in agreement with Jonh and Ousmane (2010) who found higher returns to vocational training in terms of its impact on raising agricultural productivity as compared to
primary and secondary education from rice production in Vietnam. They suggested that significant productivity gains would be achieved through the promotion of education schemes tailored to the specific technical needs of farmers.

The negative relationship between education and technical efficiency is also supported by the case of coffee farms in Vietnam. Rio et al. (2005) reported that higher education levels on small farms appeared to reduce efficiency. The reason for the negative relationship is where a labour surplus exists and higher education allows opportunity for the farm head to have other jobs outside agricultural sector, and subsequently not pay as much attention to their crops relative to other farms. Vu (2008) found that the off-farm income ratio was positively associated with the household farm head’s years of schooling, thus farmers with higher education who completed secondary and high level tend to shift to non-farm activities, and therefore their education does not contribute to improving farm technical efficiency. Vietnamese farmers may not to pay attention to cropping due to the high population pressure on limited cropping land reducing specialisation in agricultural management.

5.5.7 Age of farm head

The results in Table 5.11 are not consistent with the expectation presented in Hypothesis 9. The coefficient on age of farm head is close to zero and not statistically significant suggesting technical efficiency is not likely to be impacted by age.
Hypothesis 9 is a negative relationship between age of farm heads and technical efficiency. To be consistent with the hypothesis, a significant and negative coefficient of age in Tobit regression models should be reported. However, the results of the empirical finding show that there is no significant coefficient estimated for the age in any of the models.

In the similar context of surplus labour, other studies found farmer’s age has a negative effect on technical efficiency (Coelli and Battese, 1996; Seyoum et al., 1998; Coelli et al., 2002; Vu, 2008). In this thesis, the estimated coefficient of age is negative but close to zero and insignificant. This variable has little influence upon the observed efficiency differentials.

5.5.8 Ratio of off-farm income

The results in Table 5.11 are consistent with Hypothesis 10, a negative relationship between the ratio of off-farm income to total income and technical efficiency. The coefficient of off-farm income is positive and significantly different from zero at the 5 per cent level in Model 1 and 2. The finding is consistent with Hypothesis 10, indicating that farms with a higher share of off-farm income have higher technical efficiency.

The result of this study contradicts the result by Coelli et al. (2002) who found a negative relationship between the ratio of income earned by off-farm work and technical efficiency. The argument is that off-farm work results in neglecting their crops. However, the positive
relationship found in this thesis is consistent with that of Haji, (2006), and Solis et al., (2009). This might be the case because off-farm work may raise the income available for farm investment in diversified crops.

It has been mentioned that high education could have a negative relationship with technical efficiency because of paying less attention to cropping activities. However, in the sampled farms, only 18.9 per cent of farm heads had off-farm work and there is no correlation between the variables of farm head’s education and ratio of off-farm income (Table 5.4) because off-farm income is gained from all members in farm households not only from farm head. This indicates that the results of the relationship between share of off–farm job income and technical efficiency do not conflict with the result that there is negative impact of education of farm head on technical efficiency. Income from off-farm jobs of members of farms would contribute to improve technical efficiency through investing in inputs. The positive effect of off-farm job may be due to non-agricultural experience raising agricultural productivity.

5.5.9 Crop diversification

The results in Table 5.11 are consistent with Hypothesis 11 that crop diversification and technical efficiency are positively associated. This hypothesis was tested in Model 1 and 3 with a Herfindahl index (based on land shares of crop specialisation) and an Ogive index (based on output shares of crop specialisation) in Model 2 and 4.
The coefficient for the Herfindahl index of crop specialisation is negative and significant at the 5 per cent level. This result means that a lower Herfindahl index implies more crop diversification and increased technical efficiency. The negative coefficient of the Herfindahl index means that technical efficiency is negatively associated with specialisation, and therefore crop diversification improves technical efficiency.

The findings in model 2 and 4 are also consistent with the expectation in the Hypothesis 11. This hypothesis states that there is a negative relationship between the Ogive index of crop specialisation and technical efficiency. The coefficient of the Ogive index, which measures the concentration of output shares, is negative and statistically significant at the 5 per cent level. This result means that farms with a lower value of the Ogive index have higher technical efficiency. A lower value of the Ogive index measures a higher level of crop diversification. The negative coefficient of the Ogive index suggests that greater crop diversification leads to higher technical efficiency.

The thesis finding that crop diversification in production leads to efficiency gains supports the findings in Coelli and Fleming (2004) and Rahman (2009). Their results both support the positive effect of crop diversification on technical efficiency of farms. The results of this thesis also confirm the relevant meanings of the Herfindhal index and the Ogive index as used by Coelli and Fleming (2004) and Rahman (2009) for testing crop diversification.
The Herfindhal index, which ranges from zero for complete diversification to one for complete specialisation of farms, has meanings in terms of land allocation for crops. The Herfindhal index was calculated for each individual farm in the dataset based on the relative composition of crops in land use. The negative relationship between the Herfindhal index and technical efficiency suggests the lower Herfindhal index, which indicates the degree of diversification of land use by various crops, tends to improve technical efficiency.

The Ogive index of farms is a measure of crop specialisation as it is defined as a concentration of output share in various crops, it measures deviation from an equal distribution of output shares between farms. The negative coefficients of the Ogive index mean that an increase in the degree of crop diversification (or a decrease in the degree of specialisation) is positively associated with an increase in technical efficiency.

On the other hand, the results of this thesis is inconsistent with those of Haji (2006) who found that crop diversification showed a positive, though not significant, impact on technical efficiency; but negative and significant effect on allocative and economic efficiencies. However, the explanation may be due to the difference in the kind of farming system. Haji (2006) examined a vegetable-dominated mixed farming system and explored the number of crops as the degree of crop diversification. He claimed that the larger the number of crops a farm grows the more one would find a crop that could stand the risk factors such as lack of knowledge of soil type and input use.
Coelli and Fleming (2004) found that crop diversification significantly improves technical efficiency in a mixed food and coffee smallholder farming system in Papua New Guinea. Rahman (2009) found diversification efficiency in farming systems that produce a mix of crops including traditional and modern rice and cash crops in Bangladesh. This thesis also supports the existence of a positive relationship between crop diversification and technical efficiency in rice-based diversified cropping. The efficiency of diversification would be found in the farming system that combines a main crop such as coffee or rice and complement any crops that avoid clashes of resource allocation requirements.

Crop diversification to improve technical efficiency depends on existing infrastructure (Mahmud et al., 1994) and access to inputs and financial markets necessary for commercially oriented crops (Vedenov et al., 2007). The economy of diversification is realized in two ways: (a) by effective use of household labour and (b) by using less purchased inputs, particularly pesticides and fertilisers (Rahman, 2009). In northern region of Vietnam, the advantage of crop diversification for improving technical efficiency may suggest a combination of crops in the sampled farms enable better farming practices. This may avoid conflicts in resource allocation such as infrastructure use in the system of diversified crops in the northern part of Vietnam. In fact, there is no conflict of seasonality in the combination between rice, starchy crops, vegetables or industrial annual crops. For example, rice production exerts significant pressure on labour requirements during seasons of transplanting and harvesting seasons, whereas other crops use little labour at these times.
Increased technical efficiency occurs with diversification from rice production into cash crops such as vegetables or annual industrial crops while still retaining a significant subsistence base. According to Fleming and Hardaker (1994), Coelli and Fleming (2004), the ability of “best-practice” in small farms to make productive use of surplus family labour during slack periods is crucial in the production of subsistence and cash crops in a mixed-cropping setting; it also avoids bottlenecks in labour usage that detract from overall crop productivity. When a farm diversifies into cash production, the farmer has the opportunity to select those activities that complement each other given the seasonal nature of their labour demands to utilise family labour resources fully throughout the year. Therefore, the relationship between crop diversification and technical efficiency may depend on the combination of crops in the farming system.

5.6 Answer to research questions and summary

The results from this thesis are that the mean technical efficiency of the sample farms is 0.80. The mean pure technical and scale efficiency of these farms is 0.83 and 0.95, respectively. This measures the potential for increasing technical efficiency on the farms and supports Hypothesis 1 that there is technical inefficiency between farms. Hypothesis 2 is also confirmed that increasing returns to scale outweighs decreasing returns to scale, suggesting that the majority of farms should increase their scale to gain scale efficiency.

The Tobit models were used to test the thesis hypotheses about the determinants of technical efficiency. Table 5.12 summarises these tests. The table shows that six out of the nine findings
are consistent with their hypotheses. The results show the advantage of a large farm size (the output value), suggesting that large farm size is efficient in farming. The results also indicate that land fragmentation has a negative impact on technical efficiency. The results show that more family labour reduces technical efficiency. The results show a positive relationship between ratio of land to family labour and technical efficiency. The results show that crop diversification impacts positively on technical efficiency. The results show that the ratio of off-farm income has a significant positive impact on the technical efficiency of farms. The results are not consistent with the hypotheses on land use intensity, education and age of farm head. In general, the findings of this study are inconsistent with the inverse relationship theory between farm size and productivity. The important determinants of technical efficiency found in the present study are farm size, land fragmentation, crop diversification, family labour size, ratio of land to family labour, education of farm head and crop share of off-farm income.
Table 5.12: The summary of results of hypotheses and efficiency elasticity

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Predicted sign</th>
<th>Results consistent with hypotheses</th>
<th>Level of significance</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>H3: Farm size</td>
<td>+</td>
<td>Yes</td>
<td>$P &lt; 0.01$</td>
<td>0.097*** (0.020)</td>
</tr>
<tr>
<td>H4: Number of plots</td>
<td>-</td>
<td>Yes</td>
<td>$P &lt; 0.05$</td>
<td>-0.055*** (0.020)</td>
</tr>
<tr>
<td>H5: Land intensity</td>
<td>+</td>
<td>No</td>
<td></td>
<td>-0.063 (0.047)</td>
</tr>
<tr>
<td>H6: Family labour size</td>
<td>-</td>
<td>Yes</td>
<td>$P &lt; 0.05$</td>
<td>-0.063** (0.026)</td>
</tr>
<tr>
<td>H7: Ratio of land to family labour</td>
<td>+</td>
<td>Yes</td>
<td>$P &lt; 0.01$</td>
<td>0.058*** (0.015)</td>
</tr>
<tr>
<td>H8: Education of farm head</td>
<td>+</td>
<td>No</td>
<td>$P &lt; 0.01$</td>
<td>-0.016*** (0.018)</td>
</tr>
<tr>
<td>H9: Age of farm head</td>
<td>-</td>
<td>No</td>
<td>$P &lt; 0.01$</td>
<td>-0.001 (-0.001)</td>
</tr>
<tr>
<td>H10: Ratio of non-farm income</td>
<td>+</td>
<td>Yes</td>
<td>$P &lt; 0.05$</td>
<td>0.013** (0.013)</td>
</tr>
<tr>
<td>H11: Herfindahl index</td>
<td>-</td>
<td>Yes</td>
<td>$P &lt; 0.05$</td>
<td>-0.094** (0.038)</td>
</tr>
<tr>
<td>H11: Ogive index</td>
<td>-</td>
<td>Yes</td>
<td>$P &lt; 0.05$</td>
<td>-0.050* (0.022)</td>
</tr>
</tbody>
</table>

*** Significant at 0.01 level; ** Significant at 0.05 level; * significant at 0.10 level

Figures in parentheses are standard error
Table 5.12 presents the estimates of the elasticity of response of pure technical efficiency to each of the determinants. Farm size (total output value) has the largest impact with an elasticity of about 0.10 per cent. A 1 per cent increase in the value of output increases farm technical efficiency by nearly 0.10 per cent. Crop diversification measured by land allocation (Herfindahl index) has the same impact while diversification measured by crop value share (Ogive index) has a lower impact with a 1 per cent increase in diversification of crop sales increasing technical efficiency by around 0.05 per cent. Fragmentation, land use intensity, family labour and the land to family labour ratio have a positive impact with a 1 per cent increase in these determinants raising technical efficiency by 0.05-0.06 per cent. High school education and off-farm income are less important. A 1 per cent increase in off-farm income only increases technical efficiency by around 0.01 per cent and for high school education, reduces it by a similar amount. Age of household head has no impact on technical efficiency.

These relative elasticities demonstrate the importance of how land is used. In the context of land shortage, raising the productivity of land is crucial for technical efficiency. More output from a given land area can be achieved by multiple cropping per year or by intensifying labour use by crop diversification. These elasticities show that for these farms crop diversification is more important than land use intensity. This is logical in the context of subsistence rice production, which has already achieved the technical maximum in terms of multi-cropping per annum. In contrast, crop diversification has been driven by more recent market opening where farmers are still learning to achieve best practice and technical efficiency.
This conclusion is consistent with the results that farm size measured by value of output has the largest impact on technical efficiency while farm size measured by land area has no significant impact. It is expanding market sales through crop diversification that is the current source of improved technical efficiency in northern Vietnamese agriculture.

While land area is limited, it is important in combination with family labour as demonstrated by the interaction variable land to family labour ratio. Family labour by itself has a negative technical efficiency elasticity of around 0.06 per cent but if that family labour can be complemented with more land then this can be offset. The land to family labour ratio has a positive technical efficiency elasticity of around 0.06 per cent.

In summary, these findings show the importance of increasing farm size, especially expanding outputs by crop diversification rather than land use intensity. Limited land, fragmentation and large number of family labour have negative impacts on technical efficiency. Moreover, off-farm income has a positive impact. These suggest a policy role for government in land consolidation, encouraging farm amalgamation and labour transfer out of farming.
Chapter 6 CONCLUSION AND POLICY IMPLICATION

6.1 Introduction

This chapter first summarises the findings from this thesis, in the context of its aim and objectives (section 6.2). This is followed by an outline of the implications for a theoretical perspective of productivity of farm households in developing countries (section 6.3). The policy implications for Vietnamese agriculture policies are presented in section 6.4. Section 6.5 examines the contribution of this thesis to the existing body of academic literature on Vietnamese agricultural production. Section 6.6 outlines the limitations of this study. Section 6.7 suggests areas for future research. This is followed by the conclusion in section 6.8.

6.2 Summary of the thesis

The aim of this thesis (as described in Chapter 1) was to identify the determinants of technical efficiency of farm households in annual cropping in Northern Vietnam. This is important because Vietnam has a growing population with limited cultivated land available and this demands productive agricultural strategies. The enormous challenge to increase the productivity of food farming to feed the growing population may be met by improving farm efficiency. Chapter 2 reviewed the current research in the context of existing literature of developing countries and in Vietnam particularly. Chapter 3 identified the hypotheses in the thesis with reference to the literature on determinants of technical efficiency of farms. Chapter 4 outlined the
methodology of the thesis. The method called Data Envelopment Analysis was used to measure the technical efficiency of a farm household relative to ‘best practice’ in annual cropping. Technical efficiency at the micro-level focuses on the ability of farms to utilize the best available technology. The identification of factors which influence the level of technical efficiency of farm households is of significant importance to policy makers. The estimation of the determinants of technical efficiency is based on Tobit models. The description of data is presented in the first part of Chapter 5. The purpose of the discussion in Chapter 5 was to present the empirical findings of this thesis and identify the answers to the research questions. This chapter will present some implications of the thesis.

In this thesis, the technical and scale efficiency of the annual crops of farm households in four provinces in northern region of Vietnam were measured and the determinants of technical efficiency are estimated. These crops include rice, starchy crops, vegetables and annual industrial crops. As seen in Chapter 4, the majority of sampled farms were small and very small in terms of landholding size. The farm households were located in the north where problems of land use are pronounced due to fragmentation and small size. The empirical results of the thesis show that the important determinants of technical efficiency of annual cropping are farm size, fragmentation, family labour size, land to family labour ratio, education of farm head, off-farm income and crop diversification.

The findings of this thesis do not support an inverse relationship between farm size and technical efficiency which suggests smaller farms have an advantage in technical efficiency. These also
show the disadvantage of fragmentation of land and the negative impact of labour surplus on technical efficiency of farms. The study shows that crop diversification is an important determinant of technical efficiency. There is a negative relationship between high formal levels of education and technical efficiency. It suggests educated heads of farms tend not to be so good at managing annual crops production. Farms with a higher proportion of income from off the farm have higher technical efficiency.

6.3 Implications for size/efficiency relationship

Consistent with previous research on Vietnam, the thesis finds that there is no inverse relationship between farm size and productivity. It suggests that the theory of an inverse relationship might not be applicable in Vietnam.

The thesis supports Niroula and Thapa (2005) who argue that an inverse relationship between farm size and productivity holds little value when the impact of land fragmentation is considered and farms are driven by market-oriented production. This conclusion is consistent with the thesis results that land fragmentation is a constraint on technical efficiency. This finding of the thesis is similar to the finding of Brádisk (2006) who claimed that there is a positive relationship between farm size and technical efficiency and a negative relationship between land fragmentation and efficiency.
In some developing countries where an inverse relationship between farm size and productivity is observed, surplus family labour and land use intensity are advantageous to small farms (Zyl et al., 1995; Oduol et al., 2006; Chand et al., 2011). In contrast, in Northern Vietnam, surplus family labour is a factor decreasing technical efficiency.

Crop diversification of cereal crops or subsistence-oriented cropping systems has a stronger impact on technical efficiency than land use intensity. Increasing the share of land for cash crops may improve technical efficiency of farms. Moreover, a high ratio of off-farm income to total income can help farms invest more in cropping. These findings suggest that farms with annual cropping are driven by market-oriented production. The results of this thesis are similar to other research on Vietnam which showed that agricultural growth may depend on the system being driven by market-oriented production in farming. For example, it is demonstrated that agricultural accumulation has proceeded in rural Vietnam that has led to increased application of working capital, in particular fertiliser, and that agricultural growth has been mainly determined by the increase in purchased inputs (Akram-Lodhi, 2001, 2005). As a consequence, market-oriented production may be the reason that there is no inverse relationship between farm size and technical efficiency in Vietnam.
6.4 Implications for agricultural policy in Vietnam

6.4.1 Implications for the present land policy

The thesis tends to support the present land policy of Vietnam that regulates land consolidation because fragmentation of plots has a negative impact on technical efficiency. The second important result is the positive impact of farm size on scale efficiency. Substantial efficiency gains could be realized by increasing farm size. Therefore, active mechanisms need to be provided to enhance land transfer for consolidation.

However, the process of land transfer operates easily in principle but not in practice. For example, land transfer retains constraints on land use rights. One of the key reasons for the problem is administrative problems such as burdensome administrative procedures. A consistent process cannot be created because transactions which are subjected to case by case decisions (Marsh et al., 2004). Additionally, the land market in Vietnam is only partially complete in the formal economic sense, and is constrained in its operation by the government regulatory framework, by the capacity of newly emergent rural economic and political elites who shape the operation of the market to their advantage, and by social networks and norms which, being rooted in local communities and cultures, restrict the institutional development of the land market (Akram-Lodhi, 2007).
This thesis has policy implications in considering family labour characteristics and the land to labour ratio that contributes to enhance technical efficiency of farms. For example, the results lend support to the importance of increasing the ratio of land to family labour and decreasing the number of family members employed in farm activities for the improvement of technical efficiency. It is important to encourage farms to reduce family labour in cropping. It is thus clear that family labour surplus becomes a burden to increasing technical efficiency in annual cropping. Moreover, this thesis suggests that efficiency depends more on the ratio of land to family labour rather than land area size. This indicates that policies targeted at improving the ratio of land to family labour may be a more effective solution for labour surplus rather than changing land size of farms. It may also be possible to develop off-farm employment opportunities for family labour.

The implication for labour surplus is in agreement with Pham et al. (2007), that land policy should be integrated with policies that allow the appropriate opportunity cost of labour to be reflected at the farm level. It means that the real benefits to farm households from land consolidation may not be apparent until the real opportunity cost of farm labour begins to rise. This opportunity cost might clearly be affected by a number of factors such as the availability of employment opportunities for the farm family members and the wage rate associated with these opportunities.
6.4.2 Implications for promoting off-farm employment policy

The analysis in this thesis indicates a key future policy direction for labour transfer out of farming and supporting transition into off-farm employment. The higher share of income from off-farm jobs tends to improve technical efficiency of farms. Therefore, programs to develop existing off-farm jobs will probably directly assist households.

The VHLSS (2008) indicated off-farm jobs that were very diverse. In the sampled farms, a broad category includes food processing, unskilled work and agricultural sales and services. Therefore, the promotion of off-farm jobs may be best done through policies that assist non-agriculture sectors as a whole rather than providing sector-specific technical assistance. This would indicate the importance of policy that improves the access to credit for households farms. Access to capital is indeed a crucial factor of off-farm activities. For example, according to Sikor and Pham (2005) in the northern upland area, households with a high value of assets generated a much larger share of their income from off-farm activities than households with low assets. Moreover, public investment in physical infrastructure and vocational education is important for farms to establish their own business and to access jobs in the off-farm sectors.
6.4.3 Implications for crop diversification policy

The results of this thesis which show a positive impact of crop diversification on technical efficiency and are consistent with Rahman’s (2009) results, indicating the importance of crop diversification in farming systems that produce diversified crops to cover subsistence and cash needs. In addition, the results of this thesis indicate the diversification toward market-oriented crops is more important than land use intensity in increasing technical efficiency. In the sampled farms, farms favoring market-oriented products such as annual industrial crops, have greater efficiency than farms focusing on staple crops such as rice and maize. These results show the relevance of identifying the underlying determinants for effective policy design. For example, a policy that is targeted at increasing land use intensity may be consistent with the context of subsistence rice production, while a policy which focuses on efficiency in cropping of farm households in a context of market-orientation would focus on the importance of crop diversification in a combination of rice and cash crops. In this context, even though rice is the principle crop for food security, farm households in the north should not specialise in rice.

Motivated primarily by food security concerns, the Vietnamese state has strictly supervised the transfer of land use from rice to other crops as well as non-agricultural uses. The Decision 09/2000/NQ-CP states the priority of food security by keeping a high level of rice production. There is evidence from a 2008 rural household survey of “Vietnam Access to Resource Household Survey” project (VARHS, 2009) that shows that nearly half of all plots experienced a formal restriction on the choice of crop that could be grown. The most common restriction was to compel farmers to grow rice whereby 45.1 per cent of restricted plots had to be sown with rice
in all seasons compared to 28 per cent in 2006 (VARHS, 2008). The thesis finding that crop diversification in production leads to efficiency gains would indicate that policies aimed at keeping a high ratio of land in rice production are unlikely to improve efficiency of farms in annual cropping. That is, a farm household should determine the distribution of crops rather than specialise highly in rice. Therefore, the government should decrease restrictions on the use of land and let farmers freely choose which annual crops to grow.

Given the small size holdings of farms and high population pressure, increasing land productivity to improve technical efficiency and farmer’s income is crucial. This has led to a process of agricultural intensification. However, it has been argued that this process has caused significant damage to the physical environment and threatened the sustainability of agricultural production (Alauddin and Quiggin, 2008). Therefore, the potential to increase yields in traditional crops such as rice and maize would be limited. The findings of this thesis suggest a possible solution is for farmers to diversify their crops and to engage in the production of high-value commodities. The Vietnamese government should facilitate this process. A key policy implication is investment in appropriate infrastructure, which can complement crop diversification by improving opportunities for marketing, transportation, retail chain stores, processing and storage.

It is noted that investment in traditional activities such as irrigation should be considered with caution. Rahman (2009) found that the cropping system was highly diverse in areas with poor irrigation while irrigation projects resulted in the dominance of modern rice monoculture. Moreover, the government should adjust its funding in the research and development activities from traditional crops such as rice and maize to cash crops. There is a need to examine the
impact of the new crop varieties on farmers’ portfolios of crop choices at the farm level to avoid conflicts in resource allocation.

An important issue that limits the scope to expand cash crops is the ability of farmers to access capital. For example, due to their limited land, it is difficult for Vietnamese small farms to access credit, marketing and technology services (Akram-Lodhi, 2005). The existence of the price risk associated with uncertainties in marketing is another issue. Thus, the government could assist farmers to have informed decision-making and competitive markets. In general, the government should facilitate market condition by providing public goods rather than setting targets for specific commodities.

6.5 Contributions of the thesis

This thesis has made a number of contributions to the literature. First, this is the first study on technical efficiency of annual cropping on farms in Vietnam. In other studies (Vu, 2008; Huynh and Yabe, 2011) on technical efficiency of farms households in Vietnam, the focus has been on rice to find ways to improve its production as it is the commodity commonly thought to be of comparative advantage for Vietnam. In the thesis, the productions of rice and other annual crops is investigated to explore the efficiency in annual crops in the context of crop diversification. First, these crops are considered as a major source of food for household consumption as well as other source of household income. Thus, crop diversification is examined to help policy makers
consider policies to raise technical efficiency of farm households in cultivating annual crops. Second, as seen in Chapter 4, the majority of sampled farms were small and very small in terms of annual landholder size. For farm households located in the north of Vietnam the issue of land use is pronounced in fragmentation and small size. Therefore, the study of annual crops provides a better understanding of behavior of farms in using land for annual crops to help policy makers assess the present land policy and encourage desired strategy to promote agricultural growth.

Second, the findings of the thesis assists policy makers to better understand the determinants of technical efficiency which is a meaningful measure to assess production among farms. The results reveal that crop diversification should be a desired strategy to promote annual cropping growth as it has a positive impact on technical efficiency. This helps to inform the crop diversification policy.

Third, this thesis contributes to the literature on the inverse relationship between farm size and technical efficiency by identifying its absence in the context of land scarcity and a market oriented economy. The thesis also contributes to the literature on the impact of crop diversification on technical efficiency of farms in developing countries, particularly where government policies favour rice production over market allocation of cropping. The findings of this thesis supports a more market oriented diversity of cropping.
6.6 Limitations of the research

The findings in this thesis could be interpreted within the context of a number of methodological limitations relating to data collection. The first limitation relates to data on prices of input factors. In the data of the VHLSS 2008, there is a gap on such variables as prices of land and labour to fully examine economic efficiency. Examination of economic efficiency can help to understand the effect of efficiency on input use between farms.

Second, missing variables are also a data limitation. For example, the informal and vocational education of farmers was not available in the data set. These factors can be important to identify and confirm which kind of knowledge and education of farmers is critical to improving technical efficiency.

The third limitation relates to assessing the impact of crop diversification. The finding of the study may be clearer if it were to examine further the existence of economies of diversification among crop enterprises. To examine the existence of diversification, economies can help to better understand whether diversification into various crop enterprises leads to gains in efficiency and which combinations between subsistence production and cash crops have higher economic gain from better allocation of resource or productivity gains. However, in the sampled data, it was difficult to identify the pair of outputs in terms of input allocation for these combinations. Moreover, it was also hard to specify a production function given different characteristics of agricultural production between provinces in the area considered, the northern region of
Vietnam, to examine diversification economies. This encourages further research to solve this particular issue.

6.7 Further research

The models used in this thesis can be enhanced by better measurement of education of farm heads. This thesis has shown that it is not easy to explain the relationship between education of farm heads and efficiency, thus it may be essential to examine the relationship between efficiency and informal education and vocational education to have a better explanation about farm heads’ education. In addition, it is also important to conduct further research into the influence of irrigation, infrastructure, credit access and environmental factors on technical efficiency in diversified farming systems, to better understand the specific determinants in the context of crop diversification.

This thesis can be extended to examine the effect of crop diversification. Even though it has been found that crop diversification is positively related to technical efficiency, another line of research can be developed to investigate the particular combinations of annual crops to inform farmers on how and what to choose in cropping to get better productivity gains. A production function for crop production that can help us examine economies of diversification could be applied in a further study. In this case, Stochastic Frontier Approach could be used to allow for possible interactions including deterministic and stochastic part of the model.
The emphasis of this thesis was on technical efficiency and its decomposition into pure technical efficiency and scale efficiency. This may be insufficient to identify the source of inefficiency in agricultural production. According to Hadley et al., (2013), input mix inefficiency could be more important than either pure technical or scale efficiency. Farm households may be particularly susceptible to input mix inefficiency because of restrictions on the existence of technologies in response to changes in production and market conditions; over-specialisation in input use in a situation of diminishing returns to inputs; and the potential for inconsistency in attempting to reach points of allocative efficiency and mix efficiency in input use (Hadley et al., 2013). Therefore, the issue of input mix inefficiency should be considered in a further research to better know the relative frequency of technical, scale and mix inefficiency.

6.8 Conclusion

This chapter has presented the summary, implications, contributions as well as limitations of the research and suggestion for future research. The thesis focused on technical efficiency of farms in annual cropping, including rice in Northern Vietnam where there are limitations in land use such as fragmentation and small land holdings. With a rising population and land scarcity placing pressure on agricultural growth, this thesis aimed to extend the body of literature on technical efficiency of farms in developing countries. The investigation in this thesis on determinants of technical efficiency paid particular attention to the influence of farm size, land fragmentation, land use intensity, family labour, ratio of land to labour, education, age, off-farm work and crop diversification. It is important to understand the determinants of technical
efficiency to help inform policies on land use, to suggest off-farm employment policy and to explore the crop diversification policy.

The findings of this thesis suggest that crop diversification from rice to cash crops should be a desired strategy to promote agricultural growth in Northern region of Vietnam. The Vietnamese government should assist farmers to promote the process of crop diversification by providing public goods and research and development activities, rather than setting targets for specific commodities. It has been seen that in the context of diversified crops, including rice, land fragmentation and labour surplus are constraints on improving technical efficiency. While there is a positive relationship between farm size and technical efficiency, the government has a possible role in terms of assisting farmers, particularly in small farms, to engage in high-value cropping. This role is supported by a framework that facilitates market conditions and programs for labour transfer out of farming.

To extend this work, further research should be conducted into the influence of informal education, extension services, irrigation, infrastructure, environmental factors and crop diversification in the context of particular combinations of crops. This would allow a greater understanding of farm-specific effects and enhance understanding of the benefits of diversified cropping.
References


Wilson, P.W., 2009a *Fear 1.12 User’s Guide* Department of Economics, University of Texas, Austin, Texas.


Appendix

Figure A.1: Frequency of Land area
Figure A.2: Frequency of Seed

Figure A.3: Frequency of Fertilizer
Figure A.4: Frequency of Pesticide

Figure A.5: Frequency of Equipment
Figure A.6: Frequency of Other cost

Figure A.7: Frequency of Family Labour
Figure A.8: Frequency of Output

Figure A.9: Land against Output
Figure A.10: Seed against land area

Figure A.11: Seed against output
Figure A.12: Fertiliser against land area

Figure A.13: Fertiliser against Output
Figure A.14: Pesticide against land area

Figure A.15: Pesticide against Output
Figure A.16: Equipment against land area

Figure A.17: Equipment against Output
Figure A.18: Other cost against land area

Figure A.19: Other cost against Output
Figure A.20: Family labour against land area

Figure A.21: Family labour against Output
Figure A.22: Pure technical efficiency against Farm size

Figure A.23: Pure technical efficiency against numbers of plot
Figure A.24: Pure technical efficiency against land use intensity

[Scatter plot showing the relationship between technical efficiency (TEvrs) and land use intensity.]
Figure A.25: pure technical efficiency against family labour

Figure A.26: Pure technical efficiency against ratio of land to family labour
Figure A.27: Pure technical efficiency against Year of education
Figure A.28: Pure technical efficiency against age

Figure A.29: Pure technical efficiency against Ratio of off-farm income
Figure A.30: Pure technical efficiency against Herfindahl index

Figure A.31: Pure technical efficiency against Ogive index
The plots on family labour and land/family labour to tell an economic story about relatively fixed family labour preventing farmers from taking advantage of the most scale efficient technologies. The land intensity seems to suggest that there is a weak positive relationship with more cropping per hectare. Number of plots is clearly damaging scale efficiency. Higher output value allows more scale efficiency. This can be related to the specialisation indexes which show more diversification gives more scale efficiency. The implication is that diversification allows the adoption of farming techniques which make more efficient use of relatively fixed family labour.

Figure A.32: Scale efficiency against farm size
Figure A.33: Scale efficiency against number of plot
Figure A.34: Scale efficiency against land intensity

Figure A.35: Scale efficiency family labour size
Figure A.36: Scale efficiency against ratio of land to family labour
Figure A.37: Scale efficiency against Year of education

Figure A.38: Scale efficiency against age
Figure A.39: Scale efficiency against ratio of off-farm income
Figure A.40: Scale efficiency against Herfindahl index

Figure A.41: Scale efficiency against Ogive index