Driving and Restraining Forces for Economic and Technical Efficiency in Dairy Farms

What are the Effects of Technology and Management?

Helena Hansson

Faculty of Natural Resources and Agricultural Sciences
Department of Economics
Uppsala

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Abstract

The overall aim of this study was to analyze what drives and restrains efficient dairy production, based on data from dairy farms in Sweden. Key back ground factors of the study was that Swedish farms are getting larger and fewer, the Mid Term Review which changes the market situation and the evidence from several international studies that dairy farms can become more efficient than they are. The literature revealed three themes which were considered as fruitful conceptual frameworks for the analysis: the overall structure of inefficiency, the farm itself and the farmer managerial capacity. The first theme was analyzed in Paper I and II, the second theme in Paper III and the third in Paper IV. The study was based on farm accounting data from Statistics Sweden, a database of gross margin budgets for different agricultural production lines and regions in Sweden (Agriwise), a dairy cow recording scheme and a mail-questionnaire. All papers were based on data envelopment efficiency scores and regression analyzes. Paper I analyzed the structure of inefficiency by considering which efficiency perspective (input or output) offers the more opportunities for improvements. Further, the links between management's critical success factors (MCSFs) and efficiency were analyzed. It was concluded that especially the allocative input efficiency could be improved. Moreover, the links between MCSFs and efficiency were typically weak. Paper II continued to analyze the overall structure of inefficiency by analyzing how farm size affected farm level efficiency. It was concluded that technical and allocative efficiency scores are typically affected by farm size in opposite ways. Paper III analyzed how aspects of the farm itself, typically determined in the long-run strategic management, affected farm efficiency. It was e.g. concluded that high focus on dairy production restrains efficiency, while a discussion partner drives efficiency. Paper IV analyzed how differences in farmer managerial capacity, i.e. differences in personal aspects and decision making characteristics influenced farm efficiency. It was e.g. concluded that education in agriculture and participation in study circles drive efficiency whereas a positive profitability perception restrains efficiency.

Keywords: allocative efficiency, dairy farms, decision making, data envelopment analysis, farm size, economic efficiency, management's critical success factors, managerial capacity, regression analysis, strategic management, technical efficiency

Author's address: Helena Hansson, Department of Economics, Box 7013, 750 07 Uppsala, Sweden. *E-mail:* Helena.Hansson@ekon.slu.se

Dedication

To Ola, my husband, for all your love and support. Without you, I am nothing. With you, I can be everything.

To my parents, Carin and Bengt Johansson. I never knew when I was a little girl that my childhood at our family farm would help me write my PhD thesis.

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Hansson, H. (2007). The links between management's critical success factors and farm level economic performance on dairy farms in Sweden. *Food Economics - Acta Agricult Scand C.* 4: 77-88.

II Hansson, H. Are larger farms more efficient? A study of the relationships between farm level efficiency and size in Swedish dairy farms. (*Submitted to Agricultural and Food Science*)

III Hansson, H. (2007). Strategy factors as drivers and restraints on dairy farm performance: Evidence from Sweden. *Agricultural Systems.* 94: 726-737.

IV Hansson, H. How can farmer managerial capacity contribute to improved farm performance? A study of dairy farms in Sweden. (*Submitted to Food Economics-Acta Agricult Scand C, revised first round*)

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1 Introduction

This thesis is a collection of papers all discussing different aspects of management and farm level efficiency in Swedish dairy farms. Understanding why some dairy farms succeed in their farming, make profits and have flourishing businesses, while some do not is a pressing question. Knowledge of this is of course of great importance to the farmers themselves. If it is understood why some farmers succeed, less profitable farmers can learn from the successful ones and become more profitable. However the question is pressing also because farms create opportunities for employment at the countryside. Further, farms with grazing livestock are a prerequisite for biodiversity. In this thesis I elaborate on the question why some farms succeed in their business and why some do not succeed. Especially, I focus on how various aspects of technology, long-run strategic choices and farm management contribute to more efficient farms[1].

The background for the research is firstly the substantial structural changes that are occurring at Swedish dairy farms at present. Between 1990 and 2005, the Swedish dairy farms decreased by 67%, from 25 921 farms to 8 548 farms (Statistics Sweden 2006). During the same time the average herd size more than doubled. In 1990 it was 22 cows, and in 2005 it was 46 cows (Statistics Sweden 2006). The amount of milk produced decreased by 8% (Statistics Sweden 2006). These figures suggest that Swedish dairy farms are becoming fewer and larger.

Secondly, while the farms get fewer and larger, the Mid Term Review, which is part of the CAP reform, changes the support levels so that they are no longer proportional to the production level. This means that the market

[1] The effect of differences in animal breed, breeding and feedstuff strategies were not included in this thesis. However they may indeed affect farm efficiency and were studied in Johansson and Öhlmér (2007).

situation of the farms change, which is likely to cause new managerial challenges at the farms.

Thirdly, a key background factor for the thesis is that several international efficiency studies on dairy and related livestock farms show some important and unambiguous results: the profits at these farms would increase if their inputs or outputs were allocated more optimally. In efficiency studies, each individual firm is compared to the best practice in the sample at hand. Thus, the results show that if all farms were as good as the best ones, efficiency could increase. In Sweden, Heshmati and Kumbhakar (1994) found that outputs could increase on average nearly 20% if the dairy farmers produced as much as they could, given their inputs. They studied four panels of farms during 1976 - 1988, excluding 1985 and found levels of technical output efficiency of on average between 81% and 83%. Lawson et al. (2004) studied technical output efficiency in Danish dairy farms, and found that they could increase their outputs by about 5%. Bravo-Ureta and Rieger (1991) found similar levels of technical input efficiency as Heshmati and Kumbhakar (1994) for dairy farms in New England. In that study they also estimated farm level economic and allocative input efficiency, finding average levels of 70.2% and 84.6% respectively. Their results imply that the New England farms could reduce their costs by almost 30% if they allocated their inputs in a cost minimizing way and did not over use any of their inputs. A common feature of all these referred studies is that they base their conclusions on stochastic frontier analyses (SFA). An alternative method is the data envelopment analysis (DEA). This method was used in a study by Tauer (1993) who reported average technical input efficiency of 85% and allocative input efficiency of 70% for New York dairy farms. DEA was also used in a study by Oude Lansink et al. (2002) to assess the technical input efficiency of Finnish livestock farms. They found an average efficiency level of 69% for conventional farms and 93% for organic farms. Although the literature shows that dairy farms, on average, can increase their profits, it is not possible to argue in what studies, or in what countries, the more efficient farms are found. Differences in research method (Coelli et al. 2005) cause at least some of the differences. Furthermore, differences in data and variable specification may cause differences in average efficiency levels. Because both SFA and DEA estimates an efficient frontier based on the results of the most successful farms in the sample, low average levels of farm level efficiency can be argued to show that there is high variation in the efficiency levels. Consequently, some farms are much more efficient than other farms.

1.1 Problem

The background of my thesis shows that *i)* the Swedish dairy farms undergo considerable structural changes, *ii)* the market conditions for these farms are changing and *iii)* international studies reveal that dairy farms, including the Swedish ones, can increase their profits by becoming more efficient (Bravo-Ureta and Rieger, 1991; Tauer, 1993; Heshmati and Kumbakar, 1994; Oude Lansink et al. 2002; Lawson et al. 2004). The first two developments change the environment in which the dairy farmers are working. These developments are likely to give raise to new challenges facing the dairy farmer as business owners, which they are not familiar with to any larger extent. For instance, the farms are likely to start having employees and a higher debt-equity ratio. Sensitivity to slacks due to inefficient production is likely to become more severe. In this setting, the management aspect of dairy farms will become more important. The developments are important not only because the business style of the dairy farmers need to change, but also the bulk of knowledge of their advisors and business partners will have to develop so that they can meet the requirements of the new dairy farm environment. The evidence that dairy farms can improve their profits by becoming more efficient naturally raises questions such as: What are the characteristics of successful dairy farms? What drives successful dairy farming? What restrains it? Knowledge of what constitutes driving and restraining forces for successful dairy farming is essential both to assist farms that are not as efficient as they could be and to assist even the efficient farms to become more sustainable in a changing surrounding world.

1.2 Literature review

Classical literature on firm behaviour offers several dimensions to explain how firms work both internally as well as in their environments and how they act to be sustainable. Although not necessarily written to explain why production is inefficient, the classical literature offers a background to understand why firm behaviour deviates from what is rational and efficient. Simon[2] (1997) describes behaviour in firms principally by discussing how decisions are made in organizations. He points out that time, abilities, values and knowledge of individuals constrain decision making such that rationality is constrained. Furthermore, Simon (1997) maintains that when individuals have their attention set in some direction, this tends to be relatively persistent over time. Arguably, these characteristics should influence firm

[2] Reprinted version of Simon's classical book, first printed in 1945.

behaviour. Cyert and March (1963) express four concepts that they argue as fundamental to understand firms: Quasi resolution to conflict, avoidance of uncertainty, problemistic search and organizational learning, which all add to understand firm behaviour. By quasi resolution to conflicts they argue that because there are always different goals in firms that are in conflict with each other, e.g. large market shares and profits, conflicts arise which are attended sequentially and by certain decision rules. Avoidance of uncertainty is the behaviour that arises because firms have a short-sighted behaviour, in that they act by responding to short-run problems rather than through long-run strategies. Short-run problems are handled by e.g. setting standards with the environment to reduce or remove uncertainty. By problemistic search, Cyert and March (1963) mean that search is stimulated by an awareness of a problem and that search aims to find a solution to the problem. Finally, the organization learns when the individuals adjust to new situations. Pfeffer and Salancik (1978) offer a resource dependence perspective to how firms act and develop. In this perspective, firms are understood in the context in which they exist. Other firms or individuals drive or restrain the behaviour of a particular firm, when the firm responds to the environment. Thus firms exist in interdependence with other firms and individuals, which determines their development.

The resource based view (RBV) is another stream of literature which generates fruitful insights into why some firms are successful. Barney (1991) and Barney et al. (2001) present RBV as a theory that describes the sustained competitive advantage, i.e. success, of firms from the resources and capabilities the firm controls. Resources in this sense are a wide concept, covering both tangible and intangible assets, including the management skills of the people in the firm, its organization and information. The RBV argues that possession of unique resources that are difficult to imitate by other firms leads to sustained competitive advantage (Barney, 1991). In the context of this thesis, i.e. to understand why dairy farms are not as efficient as they can be, the RBV offers a fruitful framework in that it suggests that reasons for successful farming lie in the resources controlled by the farm. This can be compared to e.g. Porter (1980) who describes strategic management - and thus in the continuation keys for success - as adjusting properly to the surrounding environment, such as the behaviour of competitors. If the studied resources are controlled by the firm, they should at least to some extent be adjustable by the firm. Thus, less efficient farms can then adjust their resources towards the better.

1.2.1 Suggestions to why farms are not efficient

Literature on farm management emphasize the importance of goals and values of farmers as motivations for being a farmer and as explanations for why farmers do not always maximize profits. For instance, as argued in Boehlje and Eidman (1984), students of agriculture need to recognize the specific characteristics of farms such as the closeness between the family and the farm. Normally it is not possible to separate the business from the family and the leisure time. In this setting, Boehlje and Eidman (1984) argue that other goals than profit maximization may more easily come to the farmer's mind, for instance controlling a larger farm or having a low debt-equity ratio. Gasson (1973) divides goals and values of farmers into four groups: instrumental, social, expressive and intrinsic. Of these, social and expressive gaoals are likely to affect farm performance negatively, because focus is on gaining prestige as well as being creative and original.

Differences in managerial capacity are stressed in the literature as conceivable reasons for why farms differ in level of efficiency (Rougoor et al. 1998; Wilson et al. 1998; Nuthal 2001). Rougoor et al. (1998) developed a framework which showed the link between managerial capacity, in terms of personal aspects of the farmer and the decision making process, and farm level efficiency. Beyond personal characteristics such as the age, education and experience of the farmer, economic psychological aspects are interesting in explaining farmer behaviour. The decision making process of farmers was described by Öhlmér et al. (1998). They described how farmers make decisions, rather than how they should make decisions. Based on 18 case studies, the decision making process was suggested to consist of four phases: problem detection, problem definition, analysis and choice, and implementation. Moreover, each phase consists of four sub processes: searching for information and paying attention, planning, evaluating and choosing, and bearing responsibility.

In the managerial situation, information handling is an essential part to detect and solve problems: Klein et al. (2005) argue that interpretation of information from the environment is a prerequisite to influence one's situation. Two mental systems can be at work when individuals interpret and act on information: the tacit and the deliberate systems (Hogart, 2001). When the tacit system is at work, information is interpreted with the aid of previous experiences and values. In the deliberate system, careful calculations play a prominent role. Because the deliberate system is costly, Hogart (2001) argues that it is plausible to assume that the experience-based, tacit system is the default system and that the deliberate system is used more scarcely. The tacit system is developed with experience, which works to strengthen the individual's mental models (Klein et al. 2005). However, if experience is acquired in a wicked environment, it will cause the tacit system to produce dysfunctional behaviour (Hogarth, 2001).

Strategic management is the long-term process where aspects that are important for the performance of the farm are taken into consideration. Several factors that are decided on in the strategic management are difficult to change in the short run, and therefore these factors lay a basis for the farm. Strategic questions were emphasized by Harling (1992) who found that successful farmers tend to think in terms of strategic management to a greater extent compared to their less successful counterparts. Lee et al. (1999) described three environments that influence firm strategy: external, operational and internal. The firm has no control over the external environment, which corresponds to macro-economic conditions. The operational environment describes the market situation, and Lee et al. (1999) maintain that the firm may have some control over this environment. The internal environment contains resources under direct control of the firm. I argue that yet another dimension should be added: the micro-social environment. The farm family is often stated as being of major importance for the farm business (Gasson et al. 1988; Harling and Quail 1990). The micro-social environment consequently describes potential driving and restraining forces in the nearest social environment in which the farm exists.

Apart from the descriptive understanding of the management at the farm, analyses of managerial devices used by farmers to manage their farms are an essential part to understand why farms are not as efficient as they can be. The managerial device critical success factors were shown by Huirne et al. (1997) to be used and considered as important by dairy farmers. These factors are defined as indicators aimed at pointing out successful business management (Rockart, 1979). Management's critical success factors consist of a broad range of factors, both financial and non-financial and can be used both for comparisons over time as well as between farms.

1.2.2 Efficiency studies and analyses of causes of inefficiency

Efficiency studies as they are known today began with the seminal paper by Farrell (1957) who gave precise definitions of efficiency in firms. Efficiency is defined from two perspectives: the input (cost) perspective and the output (revenue) perspective. In both perspectives, three main efficiency scores are defined: economic, technical and allocative efficiencies. Methodology to estimate efficiency was established by Aigner et al. (1977) and Meeusen and van den Broeck (1977) who introduced an econometric way of estimating efficiency, as well as by Charnes et al. (1978) who introduced mathematical programming to calculate the efficiency scores. Since then, numerous applications on firm level efficiency have been made in the empirical literature, with applications to a broad array of firms. To the best of my knowledge, none of these applications have estimated all major efficiency scores. Either focus has been on one perspective, or on only one efficiency score. The most commonly considered efficiency score is the technical efficiency score.

In the efficiency literature, it is common to evaluate how some explanatory variables affect efficiency. Examples in the agricultural literature are Bravo-Ureta and Rieger, 1991; Sharma et al. 1999; Coelli et al. 2002; Iraizoz et al. 2003; Helfand and Levine 2004; Latruffe et al. 2005. Farm size is a recursive determinant of efficiency. In light of the development in Sweden where farms grow fast, it is urgent to understand how farm size affects efficiency. Some authors have found a relationship between the physical size of the farm and efficiency. Most of them have made their applications to other farms than dairy (for example Helfand and Levine 2004; Iráizoz et al. 2003 and Sharma et al. 1999), but Bravo-Ureta and Rieger (1991) studied the effect of size on dairy farms in New England. In most of these studies the relationship is positive, however the relationships are not completely clear across studies.

A common characteristic of the literature is that the analyses of the determinants of efficiency are conducted only in a broad outline. Even though differences in management are widely recognized as essential when trying to explain differences in farm efficiency, previous literature that has statistically tested what explains efficiency has generally only broadly covered these factors. Normally factors such as the age or the education of the farmer are included as an approximation of the management factor. Decision making is omitted in most of the studies. Only a few studies exist that have included aspects of strategic management and decision making in light of farm level efficiency. For example, Wilson et al. (2001) included business goal and the number of information sources used in the decision making process as explanatory variables for technical inefficiencies at wheat farms in England. Trip et al. (2002) modelled technical inefficiencies as dependent on the goals of the manager and the quality of the decision making process, in terms of planning, data recording and evaluation. Aspects of strategic management were studied in light of farm level efficiency in de Koeijer et al. (2003) and Ondersteijen et al. (2003).

1.2.3 Synthesis of literature and refined research questions

Three broad themes emerge as fruitful to cover to understand what drives and restrains efficiency in dairy farms and consequently to understand how the farms can develop. First, we need to better understand the structure of inefficiency in the dairy production. This triggers research questions such as: What efficiency perspective and score indicate the more problematic part and consequently the more important part for the farmers to focus on if they are to become more efficient? How good are the dairy farm management's critical success factors at predicting farm efficiency? How does farm size affect efficiency?

Second, the effect of characteristics describing the farm itself needs to be understood. This involves understanding how aspects decided in the long-run strategic decision making affect efficiency. In particular, determinants of the external-operational and internal environments (Lee et al. 1999) as well as the micro-social environment are essential to analyze.

Third, further and deeper analyses of the farmer managerial capacity, in terms of farmer characteristics and decision making as suggested by Rougoor et al. (1998) are vital to understand how farmers can be supported to become better at managing their farms.

Table 1 shows a list of refined research questions and their study object(s), based on the literature review.

Table 1. *The research questions and their study object(s) covered in the thesis.*

Themes and research questions	Study object(s)
The structure of inefficiency What efficiency score is the more problematic? Are there any links between management's critical success factors and efficiency according to microeconomic theory? Are larger farms more efficient?	The overall structure of efficiency
The farm itself What are the effects of factors decided in the long-run strategic decision making?	The external-operational environment of the farm, the farm as such (its internal environment) and the micro-social environment.
The farmer managerial capacity What are the effects of the managerial capacity of the farmer?	The personal characteristics and decision making approach of the farmer him- or herself.

1.3 Aim of the thesis

The overall aim of all papers in this thesis is to provide empirical evidence of how potential driving and restraining forces at the farm and in its environment contribute to or prevent farm level success. A further ambition of the thesis is to conduct at least some of the research at such a detailed level that it is directly applicable at the individual farm. The common aim of the thesis is divided into four sub-aims:

- To link commonly used management's critical success factors (MCSFs) to measures of farm cost and revenue efficiency in dairy farms, to evaluate the usefulness of these MCSFs in indicating good economic performance. A means to this aim is to analyze the overall structure of inefficiency by evaluating all major aspects of farm level efficiency.

- To investigate how farm level economic, technical and allocative input efficiencies are affected by differences in farm size, as well as to investigate the scale efficiencies and effects.

- To provide empirical evidence on the impact of important potential driving or restraining forces on farm strategy, and therefore on farm performance.

- To investigate the impact of personal aspects and decision-making characteristics on farm level efficiency, as well as to investigate the impacts of personal aspects on the decision-making characteristics that prove important for farm efficiency.

1.4 Contribution to the literature

This thesis contributes to the existing farm management literature by analyzing structural and managerial aspects in light of microeconomic efficiency concepts. This means that deviations from normative microeconomic theories are explained by managerial aspects, such as the outcome of strategic management or managerial capacity. The research is different from previous literature studying efficiency and productivity at farms, and thereby contributes to the literature, in four major respects.

First, the thesis includes driving and restraining forces for farm level efficiency that are studied at more detailed level compared to previous literature. The aim has been to study determinants of efficiency at such a detailed level that the results can be used in practical managerial advisory situations.

Second, the research contributes by focusing on the connection between management areas and farm level efficiency where research is basically missing. The link between critical success factors and efficiency has, to the best of my knowledge, not previously been studied, neither have factors that are potential driving or restraining forces on farm strategy and their link with efficiency. Further, empirical analyses of how differences in information handling in the decision-making process contributes to efficiency is lacking in previous literature, and this research is an attempt to bridge that.

Third, this research studies the connection between managerial capacity and farm level efficiency at dairy farms. Previous literature that seriously considers the influence of managerial capacity aspects has not focused on dairy farms, or even on livestock farms.

Fourth, the effects of efficiency are evaluated taking all major efficiency scores (i.e. economic, allocative and technical) into account. Previous literature that seriously considers the managerial capacity has focused on technical efficiency, although there are no clear reasons why the same managerial capacity aspects would affect the allocative and economic efficiencies as well.

2 Efficiency as a way of analyzing farm performance

As already mentioned in the literature review, efficiency studies normally builds on the framework developed by Farrell (1957), which defines efficiency from an input and output perspective. The input perspective focuses on the cost side, i.e. how much inputs or costs can be reduced, while the given amounts of outputs are still produced. The output side, on the other hand, focuses on the revenue side and measures how much output or revenue can be increased while the given amounts of inputs are used. Three main types of efficiency scores are defined in each perspective: economic, technical and allocative. Technical efficiency measures how much inputs can be reduced given the level of outputs (input efficiency) or how much outputs can be increased given the level of inputs (output efficiency). Allocative efficiency measures how much costs can be reduced if the combination of inputs was optimal according to prices (input efficiency) or how much revenues can increase if the combination of outputs was optimal according to prices (output efficiency). Economic efficiency is argued to measure overall efficiency, in that it is a combined measure of both technical and allocative efficiencies. If constant return to scale is assumed or the actual case, the technical efficiency score will be the same regardless of perspective: however this is not the case for economic and allocative efficiencies.

It is not self evident that successful farms should be defined according to the efficiency scores. Other ways are traditional financial ratio analyses and cost-revenue analyses. However, there is a major advantage of the efficiency approach: it evaluates the farms in a comprehensive way, in that all inputs and outputs are considered at the same time (Coelli 1995). The financial ratio analyses and the cost-revenue analyses on the other hand, compare only two aspects at a time. A critique that can be addressed against defining success according to an efficiency score is that the efficiency analysis assumes that it is desirable to improve the cost and revenue situation at the farm. If the farmer has other goals than the instrumental ones, he or she may succeed in fulfilling these goals. Nevertheless, I argue that to be sustainable in the long run, farmers need to at least consider their costs and revenues, regardless of what their primary reason for being a farmer is. As a consequence, the efficiency analysis is a convenient way of assessing farm level success.

2.1 What is efficiency and inefficiency?

To describe efficiency and inefficiency, we need to start by defining the technology. For both the input and the output perspective the firm technology T can be represented by distance functions, which can be described as collections of sets. The inputs are defined as the vectors $\mathbf{x} = (x^1,.....,x^h) \in \Re_+^h$, where *x* defines each input and h is the number of inputs. The outputs, which are produced by the inputs, are defined by the vectors $\mathbf{y} = (y^1,.....,y^m) \in \Re_+^m$, where *y* defines each output and m is the number of outputs. Production occurs according to the technology $T = \{(\mathbf{x},\mathbf{y}) \in \Re_+^{h+m} \mid \mathbf{x} \;\; can \;\; produce \;\; \mathbf{y})\}$. The properties imposed on the technology are nonemptiness, closedness, convexity and free disposability of inputs and outputs. The technology can then be described as follows, where n is the number of firms, and i is the individual firm:

$$T = \{(\mathbf{x},\mathbf{y}) : \mathbf{x} \geq \mathbf{X}\lambda, \mathbf{y} \leq \mathbf{Y}\lambda, \;\; \lambda^i \in \Re_+ (i = 1,.....,n), \sum_{i=1}^{n} \lambda^i = 1\} \quad (1)$$

The technology is thus described by all possible combinations of **x** and **y** within the boundary.

2.1.1 Input-oriented perspective

Under the input-oriented perspective, knowledge of the fully efficient isoquant makes it possible to describe the technical efficiency of the firms in the sample. If the isocost line is also known, allocative and economic efficiency can be estimated. This means that an economically input-efficient firm uses the smallest and cheapest combination of inputs to produce a given output. If single output and two inputs are assumed, the efficiency indices can be illustrated graphically as in Figure 1.

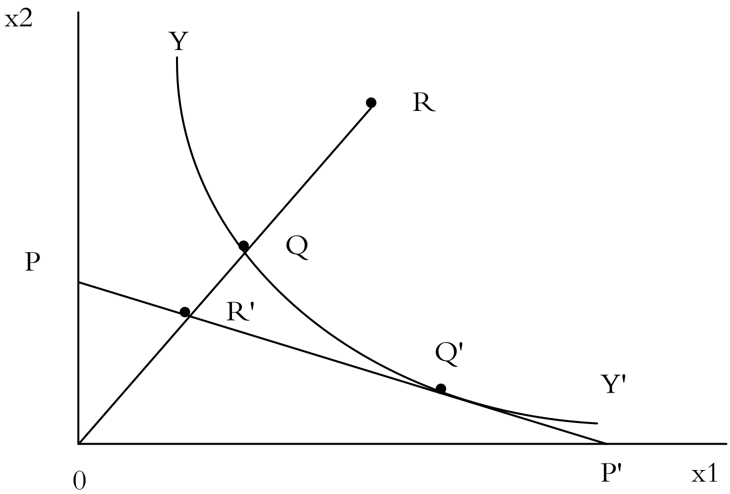

Figure 1. *Technical, allocative and economic input efficiency.*

The isoquant YY' represents the technically efficient way to produce the given input Y. The economically optimal point is the tangency point between the isoquant and the isocost line, PP', where the technical rate of substitution between the two inputs equals the economic rate of substitution. If an inefficient firm is represented by the point R and produces the amount Y, its economic efficiency is measured as 0R'/0R, and the corresponding inefficiency is 1 – 0R'/0R which is interpreted as a potential cost reduction. Economic inefficiency can consist of two parts: technical inefficiency and allocative inefficiency. The technical efficiency is measured as 0Q/0R and the allocative efficiency is measured as 0R'/0Q. The economic efficiency is then recognized as the product of technical and allocative efficiency.

2.1.2 Output-oriented perspective

In the output-oriented perspective, efficiency is evaluated keeping inputs constant. Knowledge of the fully efficient production possibility curve as well as the isorevenue line makes it possible to measure and interpret the economic output efficiency. The output oriented perspective is shown in Figure 2.

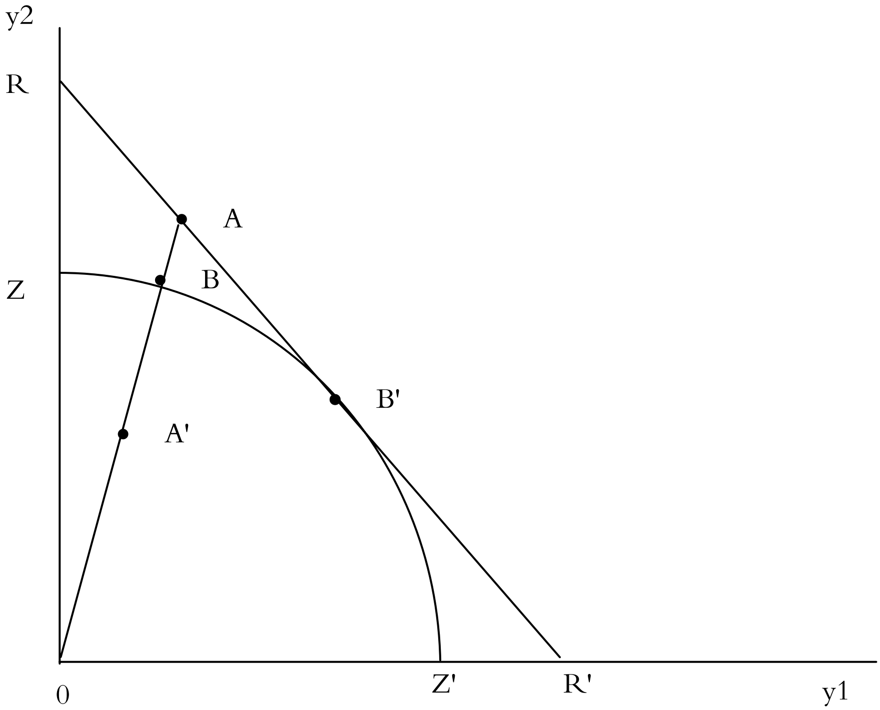

Figure 2. *Technical, allocative and economic output efficiency.*

The production possibility curve is represented by the curve ZZ' in Figure 2, which represents technically efficient combinations of production of outputs y1 and y2. The economically efficient point is B' where the marginal rate of product transformation equals the slope of the isorevenue line RR'. Consider a firm situated at point A'. Its economic output efficiency is 0A'/0A. Technical efficiency is represented by 0A'/0B and the allocative efficiency is 0B/0A.

2.1.3 Summary of the efficiency scores

According to the framework outlined above, there are six major efficiency scores. In the short run, one may argue that some inputs are fixed. In that case, the farmer can reduce the variable inputs to their optimal levels given the level of fixed inputs (Coelli et al. 2005). Consequently, nine major efficiency scores exist. These are, together with their economic interpretations, contained in Table 2.

Table 2. *The efficiency scores and their economic interpretation.*

Measure of efficiency	*Economic interpretation*
Long-run economic input efficiency	Produce a given set of outputs using the smallest and cheapest set of inputs, in the long run.
Long-run technical input efficiency	Produce a given set of outputs using the smallest set of inputs, in the long run.
Long-run allocative input efficiency	Combine inputs in the cost-minimizing way, in the long run.
Short-run economic input efficiency	Produce a given set of outputs using the smallest and cheapest set of inputs, in the short run.
Short-run technical input efficiency	Produce a given set of outputs using the smallest set of inputs, in the short run.
Short-run allocative input efficiency	Combine inputs in the cost-minimizing way, in the short run.
Economic output efficiency	Produce the maximal set of outputs, given the set of inputs, while maximizing revenue.
Technical output efficiency	Produce the maximal set of outputs, given the set of inputs.
Allocative output efficieny	Combine outputs in the revenue-maximizing way.

3 Method

The research presented in this thesis has been conducted in two independent steps in the first three papers, and in three steps in the fourth paper. First I have estimated the various efficiency scores and then I have assessed the effect of the potential driving and restraining forces on the efficiency scores with the aid of regression analysis. In the fourth paper, yet another step of regressions analysis was added.

3.1 Method to estimate the efficiency scores

The estimated levels of firm efficiency and the standard deviations of the efficiency scores can be sensitive to the method selected to estimate the efficiency scores. The two most popular techniques used to measure farm level efficiency are the data envelopment analysis, DEA (Charnes et al. 1978) and the stochastic frontier approach, SFA (Aigner et al. 1977; Meeusen and van den Broeck 1977). The DEA uses mathematical linear programming methods, whereas the SFA uses econometric methods. Both methods are empirical approaches: both DEA and SFA base their efficiency assessments on the best practice in the sample at hand, so that the best farms define the efficient frontier. This means that the efficient frontier is defined empirically. The remaining farms get efficiency scores according to their relative position to the efficient frontier. This has implications for this thesis because it implies that what is studied is how the least efficient farms can become as efficient as the best practice farms. However, it is of course possible that even the best practice farms could be more efficient if their production processes were theoretically optimized.

3.1.1 The stochastic frontier approach

SFA builds on estimating e.g. a production function with maximum likelihood techniques where the error term consists of both the random errors and of inefficiency. For instance, when estimating technical output efficiency based on cross section data the following stochastic production function can be used.

$$Y_i = f(x_i; \beta) + \varepsilon_i \tag{2}$$

where Y_i is the natural logarithm of the production of the *i*th firm, $f(x_i; \beta)$ is a function of logged input vectors x_i for the *i*th firm and the parameters to be estimated. The error term ε_i, is defined as follows:

$$\varepsilon_i = v_i - u_i \tag{3}$$

where the v_i represents the random errors, assumed to be independent and identically distributed $N(0, \sigma_v^2)$ and the u_i's, which represent the technical inefficiency, are assumed, for instance, to be identically and independently distributed non-negative truncations at zero of the $N(0, \sigma_v^2)$ distribution.

Technical output efficiency, TE_i, is defined as

$$TE_i = exp(-\mu_i) \tag{4}$$

3.1.2 The data envelopment analysis

DEA builds on solving a linear programme where a non-parametric surface is constructed over the data. The relative efficiency of each farm is determined as its relative position to the frontier. An example of a DEA programme is the following linear programme which solves for technical output efficiency.

$$\begin{aligned} & max_{\phi, \lambda}\ \phi_i \\ \text{subject to}\quad & -\phi_i\, y_i + Y\lambda \geq 0, \\ & x_i - X\lambda \geq 0, \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \\ & 1 \leq \phi_i < \infty \end{aligned} \tag{5}$$

where $1/\phi_i$ is firm *i*'s level of technical efficiency relative to the other firms in the sample. y_i is the output vector of firm *i*, Y is the output matrix of all *n* firms in the sample, x_i is the input vector of firm *i* and *X* is the output matrix of all *n* firms. λ is a vector of constants and $N1'\lambda = 1$ is a constraint to ensure the assumption of variable returns to scale. The programme is solved once for each farm in the sample. The programme builds on a radial expansion of the output vector while still remaining within the given input set, which creates projected points at the efficient surface, $Y\lambda$ and $X\lambda$. The projected points build on linear combinations of all observations in the dataset. DEA thus evaluates each observation in the sample to explore if any linear combination of the farms in the sample could produce a higher level of outputs with the given set of inputs of farm *i*. In the input case, radial contractions of the input vector are sought instead, while still remaining within the given output set.

3.1.2.1 Bootstrapping

The estimates of the DEA efficiency scores are point estimates, which are sensitive to measurement errors and sampling errors. Sampling errors refer to the situation where the firms that really define the efficient frontier have accidentally been left out of the sample. The firms that are defined as the best practice are thus not the best firms in reality. Bootstrapping for DEA (Simar and Wilson, 1998) is a method to create confidence intervals of the efficiency scores to take sampling errors into account. In the agricultural setting, bootstrapping has been considered in e.g. Brümmer (2001), Latruffe (2004) and Latruffe et al. (2005). In all these settings the homogeneous bootstrap was applied, which was also used in the paper in this thesis that considered bootstrapping (Paper I). The procedure to find the bootstrap confidence intervals is described in Simar and Wilson (2000). In brief, finding the bootstrap confidence intervals of the efficiency scores of each firm requires constructing a pseudo-dataset, based on re-sampled and original efficiency scores as well as on the original input and output data, for each firm in the sample. The DEA equations are solved again to generate new efficiency scores, based on the pseudo-dataset. The procedure is repeated at least 2000 times, generating equally many efficiency scores for each firm. The confidence interval for each firm is found by sorting the efficiency scores in decreasing order and cutting the $(\alpha/2)*100$-% scores at both ends, where α represents the desired level of significance. The remaining end points constitute the confidence interval.

3.1.3 Comparisons between SFA and DEA

In theory, the quality of the data, the appropriateness of various functional forms, and the possibility of making behavioural assumptions influence the relative appropriateness of DEA and SFA. For example, the DEA approach, compared with the SFA requires no specific functional form to be selected, neither are any behavioural assumptions needed. However, DEA is a deterministic approach, meaning that it does not account for noise in the data. All deviations from the frontier will therefore be accounted for as inefficiencies. The DEA efficiency scores are, therefore, likely to be sensitive to measurements errors and random errors. The SFA, on the other hand, accounts for random errors and has the advantage of making inference possible (see for example Coelli et al. 2005). However, SFA is likely to be sensitive to the choice of functional form.

Empirical comparisons between SFA and DEA have been done during the last years to evaluate if the results differ depending on the method chosen. Iráizoz et al. (2003) compared technical efficiency results on a sample of Spanish vegetable producers, and they found consistency between the SFA and DEA. They used a Cobb-Douglas production function to represent the SFA. Reinhard et al. (2000) compared technical and environmental efficiency (a measure computationally similar to technical efficiency) scores in a sample of Dutch dairy farms. They found that SFA generated higher technical efficiency scores as well as higher efficiency scores in two out of three environmental scores. The efficiency rankings, however, were the same across methods. The functional form considered in this case was the translog production function. Sharma et al. (1999) studied technical, allocative and economic input efficiency of swine producers in Hawaii. In their study, efficiency was measured against a Cobb-Douglas production function under the parametric approach. They found that, on average, the estimated technical and economic efficiencies were significantly higher in the SFA compared with the DEA under the assumption of constant returns to scale. Under the assumption of variable returns to scale, however, the measures were quite similar. Allocative efficiency was found to be generally higher in DEA. The efficiency ranking of the farmers in the sample was positively correlated, indicating that the two approaches assess relative efficiency to the same farms. Outside the agricultural sector, Cullinane et al. (2006) compared the results of DEA and SFA technical efficiency in a sample of container ports. The functional form of the production function was assumed to be Cobb-Douglas. They found that DEA generally yields lower efficiency scores compared with SFA, except under the assumption of half-normal distribution of the technical inefficiency where SFA yielded lower scores. The efficiency rankings were found to be the same across the methods. Furthermore, DEA efficiency scores were found to have larger variation. Coelli and Perelman (1999) compared technical efficiency scores on a sample of European railways. Their main finding was that different approaches to technical efficiency estimation gave relative efficiency to approximately the same firms. Resti (1997) compared cost efficiency scores on a sample of Italian banks. In the SFA case she used a translog cost function and she found that the two methods differed only slightly.

3.1.4 Empirical comparison between DEA and SFA in the case of this thesis

In the initial parts of the thesis work an empirical comparison between DEA and SFA based on cross-section data from Swedish milk producing farms was conducted to find out if the conclusions from previous literature was consistent even in this case (Johansson, 2006). Technical output efficiency was estimated based on a translog production function and calculated based on a DEA linear programme.

Comparisons between the DEA and SFA technical output efficiency results were based on average efficiency levels, standard deviations and ranking of efficient farms. The average technical efficiency scores from the DEA model and the SFA model were not significantly different according to both the t-test and the non-parametric Wilcoxon rank sum test. The standard deviations were larger in the DEA model compared to the SFA model. This was expected because DEA always reports some firms on the frontier, and because DEA does not account for noise in the data. The correlation between the efficiency scores from the two models was 0.722 and significant. Thus, both models give the same relative ranking of the efficient farms. These results indicate that the two methods produce similar results in my case, which is in line with previous literature (Cullinane et al. 2006; Iráizoz et al. 2003; Coelli and Perelman 1999; Sharma et al. 1999; Resti 1997)

3.1.5 Conclusion on method choice

The literature review as well as own empirical comparisons between DEA and SFA, suggests that relative efficiency is given to approximately the same firms regardless of the method used, and that DEA technical efficiency scores are generally equal to or lower than the corresponding SFA scores. Lower efficiency scores are expected since DEA is deterministic and reports all deviations from the frontier as inefficiency (Sharma et al. 1999; Brümmer 2001). Choice of method to assess the efficiency scores is thus mainly a matter of taste of the researcher. Because I experience some advantages of DEA, such as i) no need to specify functional form, ii) easy and straight forward decomposition of the efficiency scores and iii) it allows easily for multiple output, I have worked with DEA in my papers. It should be stressed, however, that this is my personal view and that other researchers, with other experiences, may be more comfortable working with SFA on basically the same grounds (except for the first one – a functional form is always needed in SFA).

3.2 Method to assess the effect of potential driving forces and hindrances on farm level efficiency

The literature describes several approaches to assess the effect of factors hypothesised to explain efficiency (see e.g. Coelli et al. 2005 for a review). The method chosen in this step depends to a large extent on the method chosen to assess the farm level efficiency scores. In my case, as motivated above, I worked with DEA. To determine the effect of several factors explaining efficiency, multiple regressions were undertaken in a second step. DEA assesses full efficiency to at least some farms in the sample, which are considered the best practice in the sample. The remaining observations get efficiency scores in comparison with this best practice. Consequently, the efficiency scores cannot have a higher value than one; and an interesting question is whether the data are censored or truncated. Data are censored if, for some reason a maximal or minimal value is put on a variable (see e.g. Kennedy 1998). This means that the dependent variable does not necessarily have the right value for those observations which have the censored value. This is what happens if, for instance, ability of students is measured by their test scores. All students getting the maximal score are not necessarily equally competent. Data are truncated if, for instance, all observations above a certain value are excluded (see e.g. Kennedy, 1998) and there exist neither dependent nor independent variables for these observations. An example is when data about wages above a certain limit are missing. In the DEA case not all farms scoring one are exactly equally efficient, because the reductions in the number of observations as well as increases in the number of variables causes the efficiency scores to be biased against one. Consequently, if the method allowed for the efficiency scores to be greater than one, some of the farms would get higher efficiency scores than one. Based on this I argue that DEA efficiency scores can be considered as censored. The censored nature of the efficiency scores has to be taken into consideration when assessing the impact of the factors explaining efficiency. In the literature (e.g. Sharma et al., 1999; Coelli et al. 2002), this is normally done by using the tobit regression, which allows for the data to be censored, in a regression analysis. Simpler alternatives, like the ordinary least square regression, may cause predicted values of efficiency to exceed one, which is not desirable.

The method can thus be described as a two-stage process, where the efficiency scores are determined in the first stage and the effects of factors hypothesized to determine efficiency are determined in a second stage regression. In a recent paper by Simar and Wilson (2007) this approach was criticized. Their criticism is based on the fact that DEA produces biased efficiency scores in small samples and because the explanatory variables in the second stage regression are correlated to the inputs and outputs used to construct the DEA efficiency scores. To overcome these problems, Simar and Wilson (2007) suggest two bootstrap algorithms, of which the second algorithm (the double loop) corrects for both problems. Afonso and Aubyn (2006) compared these bootstrap algorithms with the traditional two-step approach in an empirical setting. They found that the estimated coefficients and significance levels were very similar in all three cases. This questions the value of extra computational burden cased by the bootstrap algorithms. Furthermore, and in my case more important, following Simar and Wilson (2007) would mean that I would not be able to use large parts of my data. In my papers, I have pooled data from different sources. This gave missing values for some explanatory variables of several observations. The data on inputs and outputs used to construct the efficiency scores are complete, but the data on factors hypothesized to affect efficiency have missing variables in several cases. If the two stage approach was used, all data on inputs and outputs can be used to calculate the first stage efficiency scores. In the second stage the observations where there are no missing values on the explanatory variables were used. Following the suggestion by Simar and Wilson (2007) would have meant that large parts of my data on inputs and outputs could not be used, because all observations needed to be involved in the entire bootstrapping process.

4 Data

In order to conduct the research presented in this thesis with the research method outlined in the previous section, I needed information about how much inputs each farm use, how much outputs they produce, the prices of the inputs and outputs, and data detailing the study objects presented in Table 1. Some of these data were available in existing data sources, whereas the remaining data had to be collected through a mail questionnaire.

4.1 Inputs, outputs and prices

To construct the input and output variables needed to estimate the efficiency scores, I have used farm level accounting data available from Statistics Sweden. I have also used some additional price data from a database consisting of gross margin budgets for different agricultural production lines and regions in Sweden (www.agriwise.org). Data on prices were necessary to construct quantities of the variables, but price data were not available in the dataset from Statistics Sweden.

Statistics Sweden collects numerous data from farms, with the main purpose to be the basis of the Farm Accounting Data Network (FADN). The data consist of the balance sheet and income statement of each farm in the sample, as well as some additional data such as time worked at the farm and harvest. The dataset used for this thesis is the basic data of the FADN variables. Statistic Sweden uses a rotating panel to construct the dataset. This means that not all farms are represented each year. In my thesis, I use data from 1998 through 2002. The data collected before 1998 were presented in a very different way compared to 1998, and the data after 2002 were not yet collected when the first analyses were done. In all studies included in this thesis, the farms are represented by their own yearly average of inputs outputs and prices during the years they participated in the dataset. This is an attempt to compensate for possible random measurement errors to which DEA is sensitive.

In all papers enclosed to this thesis, the same variable specification was used to calculate the efficiency scores. Six inputs, which were thought to be the major inputs at a dairy farm were considered: fodder, labour, capital, energy, seed and fertilizer. Five outputs were considered: milk, livestock, forage, crop and "other". "Other" corresponds to all other outputs at the farm, but consists mostly of allowances.

4.2 Measures of potential driving and restraining forces

Some of the data needed to construct measures of potential driving and restraining forces for successful dairy farm performance were available in the dataset from Statistics Sweden. For example, measures of farm size and the age of the farmer were available in that dataset. Information on farm level management's critical success factors (MCSFs) came from a dairy cow recording scheme conducted by the Swedish Dairy Association. Participation in this recording scheme is voluntary to the dairy farmers, but most of the farmers participate. On a monthly basis the recording scheme gives information of cow level performance, in terms of, for example, milk yield, milk quality, diseases and fertility. In Sweden, the recording scheme year starts in September and ends in August, thus it does not follow the accounting year. I have used data beginning in year 1997/98 and ending in 2001/02.

The remaining data needed, were collected through a mail questionnaire. The development of the questionnaire started with literature reviews to find potential determinants of efficiency and a focus group meeting where a group of dairy farmers were interviewed about how they believed farms could become more efficient. During the development time the questionnaire was tested in three subsequent focus group interviews where dairy farmers were asked to fill in the questionnaire and to explain how they interpreted the questions. The questionnaire was sent to the farmers who participated in the data collection by Statistics Sweden, referred to above, and who delivered milk to a dairy plant processor, in the beginning of February 2005. Because of very heavy storms in some parts of Southern Sweden at that time, the questionnaires to farmers in the counties of Jönköping, Kronoberg, Kalmar and Blekinge were sent two weeks later to reduce negative influence on the response rate. After two reminders, the response rate was 67%, but some of the questionnaires were only partly filled out. Details on the responded questions used in each paper are presented in the respective papers. In the papers I used a less generous definition of a dairy farm which means that not all questionnaires were useful. The response rate of the farms included in the papers was 65%.

4.3 Discussion about the quality of the data

Naturally, the quality and validity of all kinds of studies depend heavily on the quality of the data used, and this thesis work is no exception. Keeping the quality of the data in mind when interpreting the results is always important. Therefore, I believe that a discussion about the quality of the data is in place before presenting the major findings in the papers. As in other studies in social sciences much of the data collected for this thesis is based on opinions of humans, which of course may cause measurement errors. This is especially important for the variables that originate from information collected through the questionnaire. For example, the mode of the person who answers a questionnaire may affect the answers. Tiredness, amount of time devoted to the questionnaire, motivation, expectations and other factors may influence the answers. Furthermore, it is possible that questions and answer models are interpreted differently by different individuals. Especially questions where the respondent is asked to rate something may be answered differently by different individuals, where "good" and "bad" may be interpreted differently by different individuals. For these reasons, the estimated coefficients of that kind of variables should be interpreted with care, only as directions. To minimize measurement errors in the questionnaire, actions such as focus groups interviews were undertaken to improve the transparency of the questions and the answer models.

The data used to calculate the efficiency scores were, as mentioned above, accounting data from Statistics Sweden and price data from Agriwise. Accounting keeping data can be subject to measurement errors if there is inconsistency in the classifications of the transactions into accounts at the farms and because of the subjectivity of, for instance, the valuations of depreciations. However, because Statistics Sweden uses an accountancy agent to collect the data, I do not have any particular reasons to believe that there are extensive errors of the above-mentioned kind. Accounting data are, however, based on historical values, which may cause problems especially with the valuation of capital, in this thesis measured as the value of buildings, inventories and production rights. The real value may therefore differ from the booked value. However, possible actions to correct for this, such as valuing all the capital at all farms would be very expensive and time consuming so these were not considered. Because individual price data are not available in the dataset from Statistics Sweden they were collected from Agriwise (www.agriwise.org). This means that the same price is assumed for all farms in a particular geographic region. Thus, differences in prices due to, for instance ability to negotiate are not included in the data. Furthermore, because quantities of inputs and outputs were for some variables calculated by dividing expenses and income with the relevant price, this means that at large farms, which may have an advantage in negotiating prices, the use of inputs may have been underestimated, and the amount of outputs overestimated. This in turn, may cause efficiency to be overestimated at these farms.

Because the data panel from Statistics Sweden ended in 2002, pooling it with the data from the questionnaire collected in the beginning of 2005 obviously implies that data from different years are pooled. If some farmers have made large changes to their dairy farms, such as investing in new barns or milking systems after 2002, this is reflected in the questionnaire but not in the accounting data from Statistics Sweden and this can influence the results. If flaws like this have affected the data, they are more likely to affect variables describing investments in fixed assets at the farm than values and management routines, which are more likely to be stable over time. However, because the coefficients of the variables describing investments in fixed assets are logical in the estimations, these possible flaws are not thought to be any problem.

Out of the data used in this thesis, the data from the Swedish Dairy Association are the data that are the least likely to be subject to measurement errors. The same product is evaluated at each farm with the same type of instruction for milk collection procedures and analysis devices in each case. Based on experience gained from this thesis work, I think that the optimal way to collect the remaining data for such a study would be by telephone interviews. Ideally, a battery of questions would be constructed and sent to the farmer well in advance of the telephone interview, so that they can prepare answers to the questions. With this approach, difficult questions can then be explained directly, and all questions are likely to be answered. However, this approach would be very time consuming and thus expensive both for the researcher and the farmers. Further, the fact that people perceive words such as "good" or "bad" differently will still remain. As a consequence, given the time and budget constraints that everyone doing research is subjected to, I think the dataset used is satisfactory.

5 The papers

The approach to study why farms are not as efficient as they can be, has been to start at a broad level and subsequently refine and detail the analysis. The analysis was started by trying to broadly understand what the main reason is for low efficiency in dairy farms. Further, the usefulness of commonly used management's critical success factors and the effects of farm size were analyzed in the beginning of the study. In the later part of the study, the effects of strategic drivers and restraints as well as the managerial capacity of the farmer were studied. As a consequence, somewhat different data and method were used in the studies. Table 3 summarizes the papers with respect to data and research method.

Table 3. *Summary of papers in the thesis with respect to data and research method.*

	Paper I	Paper II	Paper III	Paper IV
Data				
Statistics Sweden	x	x	x	x
Agriwise	x	x	x	x
Dairy cow recording scheme	x			
Questionnaire			x	x
Method				
DEA	x	x	x	x
Bootstrapping	x			
Tobit regression		x	x	x
Logistic regression	x			x

As indicated in Table 3, all papers are based on data from Statistics Sweden and Agriwise. Further, all papers are based on the DEA efficiency scores. Table 4 summarizes the papers with respect to research questions as well as to study object and categories of analyzed factors, in light of Table 1.

Table 4. *Summary of papers in the thesis with respect to research question as well as study object and categories of analyzed factors.*

	Research questions	Study object and categories of analyzed factors
Paper 1	What part of the profitability process is the more problematic? Are there any links between management's critical success factors and farm level efficiency?	The overall structure of efficiency Comparison between long-run input and output efficiency scores. Analysis of how well some common management's critical success factors from a dairy cow recording scheme work in predicting good economic performance.
Paper 2	Are larger farms more efficient?	The overall structure of efficiency How does farm size, in terms of the size of the dairy production, the whole-farm production and the number of hectares affect efficiency?
Paper 3	What are the effects of factors decided in the long-run strategic decision making?	The external-operational environment, internal and micro-social environment of the farm in terms of: Geographic location. The outcome of long-run decisions about resource allocation and use. The outcome of long-run decisions about fixed costs. The social situation of the farm
Paper 4	What are the effects of the managerial capacity of the farmer?	The personal characteristics and decision-making approach of the farmer him- or herself, in terms of: Values and attitudes. Psychological aspects. Experience. Education. Search for information for decision making. Planning, forecasting and evaluating consequences for decision making. Bearing responsibility in decision making.

As indicated in Table 4, the first two papers analyze the overall structure of efficiency in the dairy farms in Sweden. Paper III analyzes how factors that are decided in the long-run strategic decision making affect farm efficiency. Knowledge of this is important especially when new farms are started or when old ones undergo major changes. The fourth paper analyzes how managerial capacity can contribute to improved farm performance. In this paper the personal aspects of the farmer and his or her decision-making style are evaluated in light of farm efficiency.

5.1 Paper I

5.1.1 Summary of Paper I

In the paper *The links between management's critical success factors and farm level economic performance on dairy farms in Sweden* the aim was to study the relationship between cost (i.e. economic input), revenue (i.e. economic output) and profit (i.e. both economic input and output) efficiency and some commonly used management's critical success factors (MCSFs), to study the usefulness of the MCSFs in indicating good economic performance. As a means to the main aim, a second aim was to evaluate all major aspects of farm level efficiency. This paper, together with Paper II covers the first theme (as defined above) of analysing the structure of the efficiency.

The considered MCSFs were milk yield per cow, protein content in the milk, average herd fertility, mastitis ratio and involuntary culls ratio. These MCSFs are reported on a monthly basis by the Swedish Dairy Association, to all dairy farmers who participate in a dairy cow recording scheme conducted by the Swedish Dairy Association. Thus, the considered MCSFs are used regularly to indicate farm level performance.

In the first stage of the analysis, DEA long-run economic, technical and allocative input and output efficiency scores were calculated for all farms. Further, confidence intervals according to Simar and Wilson (2000) were calculated for each farm for the economic and technical efficiency scores. Comparisons between the average point estimates showed that economic input efficiency was the lowest efficiency score while the allocative output efficiency was the highest score. A closer look at the input efficiency scored revealed that the average allocative efficiency was lower than the average technical efficiency suggesting that the main reason for low economic input efficiency is poor skills among the farmers to allocate inputs in the cost-minimizing way. This suggestion is also supported by the confidence intervals.

In the second stage of the analysis, all farms that scored one on the cost efficiency score were defined as cost efficient, all farms that scored one on the revenue efficiency score were defined as revenue efficient and finally, all farms that scored one on both the cost and revenue efficiency scores were defined as profit efficient. These scores were defined as success in logistic regressions, where the dependent variables were the MCSFs defined above. The results show that only two of the considered MCSFs work as significant predictors of good economic performance. Milk yield per cow predict being cost efficient and being profit efficient. The mastitis ratio is a significant predictor of not being revenue efficient. Protein content, fertility and the involuntary culls ratio are not significant predictors of any definition of good farm performance.

5.1.2 Specific contribution of Paper I

Paper I contributes to the literature in two ways. One part of the contribution lies in the linking of traditional managerial devices, such as MCSFs to measures of economic performance. This means analyzing the accordance between measures that are commonly used at the farms as indicators of good economic performance, and the real economic performance of the farm in terms of efficiency. This also means studying the usefulness of the MCSFs in indicating good economic performance. The contribution of Paper I also lies in evaluating and comparing all major aspects of farm level efficiency, because economic, technical and allocative input and output efficiency scores were evaluated. Efficiency studies in general focus only on one efficiency score, or on one perspective, which means that they fail to give a comprehensive understanding of the efficiency of the industry studied.

5.2 Paper II

5.2.1 Summary of Paper II

The paper *Are larger farms more efficient? A study of the relationships between farm level efficiency and size in Swedish dairy farms* aimed to investigate how farm level economic, technical and allocative input efficiencies are affected by differences in farm size. Further, the paper aimed to investigate the scale efficiencies and effects to further study the potential improvements in efficiency due to larger farms. The study was motivated by the ongoing trend among Swedish dairy farms of becoming fewer and larger. When the farms become fewer and larger, it is important to understand how farm size affect farm efficiency. Previous literature does not give enough advice on how farm efficiency is affected by differences in farm size. First, previous literature does not show an unambiguous relation between farm efficiency and size. Second, it does not easily translate to North European countries because of differences in, for example, farm technology, climate and business culture. Three measures of farm size were analyzed: the size of the dairy production, the size of the whole-farm production and the physical size of the farm in terms of the number of hectares. Both linear and squared effects of these size measures were considered. Further, the scale efficiencies and effects were analyzed to gain additional insight into the relationship between efficiency and size. A sub-sample of specialized dairy farms were studied separately as well as together with the full sample of milk producing farms.

The results show that the connections between farm level efficiency and size are involved and that farm size does not influence all efficiency scores in only one direction. For instance, the linear effects of the size of the dairy production were significantly negative for technical efficiency in both groups of farms and also for economic efficiency in the full sample. None of the linear size effects influenced allocative efficiency. The significant linear effects of farm size in terms of total income were positive, suggesting that larger farms are more efficient. When the squared effects were considered, technical efficiency was first decreasing with the size of the dairy production and the number of hectares and then increasing. Allocative efficiency, on the other hand, was first increasing with the size of the dairy production and the number of hectares at the farm, and then the allocative efficiency was decreasing. The significant effects of the squared total income suggested that technical efficiency first increased and then decreased with farm size, whereas the effect was reversed for allocative efficiency. To summarize, the study shows that technical and allocative efficiency scores are typically affected by farm in opposite ways size.

Compared to previous literature, the results in this study are different from those of Bravo-Ureta and Rieger (1991), but similar to the results reported by Helfand and Levine (2004).

The average scale efficiency was high in both the full sample and the sub-sample, 95.3% and 96% respectively. These results suggests that, on average, the farms operate close to their optimal scales and would not benefit much from moving closer to their optimal scales. The results showed that in both groups several farms were operating under increasing returns to scale, which means that these farms could increase their efficiency by expanding their farms. However, also these farms have high average levels of scale efficiency, 91.8% based on the full sample and 91.7% based on the specialized sub-sample, implying that the gains from increasing farm size are small.

5.2.2 Specific contribution of Paper II

Previous studies analyze the relationship between farm efficiency and farm size (Bravo-Ureta and Rieger, 1991; Sharma et al. 1999; Iraizóz et al. 2003; Alvarez and Arias, 2004; Helfand and Levine, 2004): however the results are not clear and unambiguous. Furthermore, it is difficult to use the results of previous studies to understand how farms in Sweden are affected by differences in farm size because there are obvious differences in farming systems, climate and business culture. Given this, and the structural changes in Swedish farms and in farms in other European countries, this study contributes by adding to the understanding of how farm level efficiency is likely to develop when smaller farms become larger.

5.3 Paper III

5.3.1 Summary of Paper III

In the third paper, *Strategy factors as drivers and restraints on dairy farm performance: Evidence from Sweden,* the aim was to provide empirical evidence on the impact of important potential driving or restraining forces on farm strategy, and therefore on farm performance. Strategy factors are under consideration especially when a farmer decides to stay in business and expand the farm or when new farms are considered. An understanding of how strategy factors drives or restrains farm performance is important because they are difficult to change on a short-run basis and therefore lay a basis of the farm.

Building on Lee et al. (1999), Gasson et al. (1988) and Harling and Quail (1990) three levels of environments are defined that are potential driving and restraining forces for farm strategy and therefore on farm performance. These environments are external-operational, internal and micro-social. The external-operational environment is difficult to influence by the individual farmer. The internal and micro-social environment are to some extent controllable by the farmer, at least in the long run. The farm is embedded within these environments that are potential driving and restraining forces on the farm activities.

All nine efficiency scores were calculated and the effects of factors that determine the above-mentioned strategy environments were analyzed, with the aid of tobit regressions. The results show that several of the strategy factors are important for farm performance. For example, several geographic locations (external-internal environment) are driving forces for economic and technical efficiency. Differences in soil and climate may be reasons, but also potential differences in business culture. When the internal environment is considered, size of fields, distance to fields, bunker silo and tower silo are found to be driving forces for farm performance, while quality of forage machinery and a high focus on dairy production were found to restrain farm performance. The fact that high quality of forage machinery restrains farm performance suggests that the farmers have over-invested in forage machinery leading to too much capital tied in the forage machinery. High investments in certain production lines may also cause the farmer to be less willing to switch to other production lines even if they are more profitable at the time. It is also interesting to note that diversified farms are more efficient than specialized ones. This result is supported by findings by Hadely (2006) and Brümmer (2001). Reasons can be that diversified farms are likely to have other fully developed production lines that they can expand when the market conditions are more favourable for these production lines and thus allocate its resources where they are the more profitable at the time. Another reason may be that milk production is more difficult or less profitable compared with other agricultural production lines. In the micro-social environment co-farmers were found to be restraints on farm performance, which may indicate a hidden unemployment at the farm. Furthermore, the results showed that discussing dairy production with someone improved the skills to minimize costs. This result thus suggests that there is a learning process in the micro-social environment where farmers get ideas from each other how inputs should optimally be combined.

5.3.2 Specific contribution of Paper III

Paper III contributes to the literature by considering the relationship between farm performance and strategy factors that describe the environments in which the farm operates and which influence the farm strategy. These strategy factors lay a basis of the firm and therefore work as driving or restraining forces on farm performance. Compared to previous literature that has evaluated relationships between farm performance and strategic questions, this study was conducted at a more detailed level. The strategy factors considered are generally of the kind that they are difficult to alter in the short run. Therefore these factors are important for the farmer to consider, especially when entering the farm business or when major investments are done, because then the strategic management and formulation should be revised.

5.4 Paper IV

5.4.1 Summary of Paper IV

In Paper IV *How can farmer managerial capacity contribute to improved farm performance? A study of dairy farms in Sweden* the aim was to investigate empirically the impact of personal aspects and decision making characteristics on farm level efficiency, as well as to investigate the impacts of personal aspects on the decision making characteristics that prove important form farm efficiency. A model was developed, based on Rougoor et al. (1998) where efficiency was modeled as dependent on the decision making aspects. The decision making aspects, in turn, were modeled as dependent on the personal aspects of the farmer. I included a further connection in the model, such that the efficiency was considered as dependent on the personal aspects, both directly and indirectly. The indirect connection follows the suggestion by Rougoor et al. (1998), whereas the direct connection is justified by recognizing that personal aspects contributes to a person's general experience, and thus to a readiness to act in a certain way, without necessarily going through the deliberate decision making system. This line of reasoning is based on the tacit and deliberate systems described by Hogarth (2001).

The study was conducted in three independent steps. In the first step economic, technical and allocative long- and short-run input efficiencies were calculated with DEA (Charnes et al. 1978) as well as economic, technical and allocative output efficiencies. In a second step the direct effect of the managerial capacity aspects were estimated using tobit regressions. In the third step, logistic regressions were used to estimate the effect of personal aspects on the significant decision making aspects.

The results showed that several of the managerial capacity aspects are important determinants of farm level efficiency. Interestingly, this holds especially for the input, or cost, perspective of the efficiency scores. Personal aspects such as a positive profitability attitude towards dairy farming today, internal locus of control, agricultural education, participation in study circles and intrinsic values affect farm level efficiency in a positive way. Values of the farmer was found to influence short-run input efficiency scores to a much greater extent than the long-run input efficiency scores and the output efficiency scores. A possible explanation for this is that in the short-run intuitive decision making is more important because action alternatives are well known. In the intuitive thinking process, values are important (Klein et al. 2005). A positive profitability attitude towards future dairy farming, expressive goals and age affect efficiency negatively. Profitability perception also affects farm level efficiency in a negative way. Based on how profitability perception was measured, this implies that believing that the farm is better than it is leads to lower efficiency. None of the considered decision making aspects influenced the output, or revenue, efficiency scores significantly. A possible reason is that it is difficult to influence output prices and the output mix of a Swedish dairy farmer. Farm advisors and other farmers or colleagues are important information sources in the decision making process, leading to higher input efficiency. Further, checking the accounting and paying attention to collected information have positive effects on efficiency. Instrumental and expressive goals, as well as participation in study circles, were aspects found to influence the decision making aspects that in turn influenced efficiency positively. Based on the results, a suggested concrete way of supporting dairy farms to become more profitable is by organizing combined educational and discussion clubs where the farmers get to learn from each other as well as from professional dairy farm advisors.

5.4.2 Specific contribution of Paper IV

Paper IV contributes to the literature by analyzing the managerial capacity of the farmer at a deeper and more detailed level compared to previously. The study includes a detailed analysis of the personal aspects of the farmer, which in previous literature is only broadly handled. Personal aspects are considered to influence decision making (Lee et al. 1999) and therefore they should be important for farm performance. Furthermore, building on the reasoning of tacit knowledge (Hogart, 2001) personal aspects also contribute to a readiness to act in certain ways without necessarily going through deliberate decision making. The study also contributes by considering decision making aspects such as information sources, way of processing information and how responsibility is born, previously not studied in light of farm level efficiency. A further contribution of the study is the application on milk producing farms. Previous literature that focus on the connection between managerial capacity and farm economic performance have concentrated on wheat farms (Wilson et al. 2001) and greenhouses (Trip et al. 2002), which should differ substantially from livestock farms.

5.5 Summary of the main conclusions

Table 5 summarizes the main conclusions in the papers in light of Table 1.

Table 5. *Summary of Paper I-IV in light of Table 1.*

Theme	Conclusions
The structure of inefficiency	The input, or cost, perspective offers more opportunities for improvements in efficiency. Especially the allocative efficiency can be improved. The links between MCSFs and economic performance according to the efficiency scores are not necessarily strong. Only two MCSFs out of five were signficant predictors of efficiency. The relationships between farm size and farm level efficiency are involved and the results show that the technical and allocative efficiency scores are typically affected in opposite ways by farm size.
The farm itself	External-operational environment in terms of geographic location can drive efficiency. In the internal environment, size of fields, distance to fields, bunker silo and tower silo drive efficiency. High quality of forage machinery and high focus on dairy production restrain efficiency. In the micro-social environment, a discussion partner drives efficiency, while co-farmers restrain efficiency
The farmer managerial capacity	Of the personal aspects of the farmer, a positive profitability attitude towards dairy farming today, internal locus of control, agricultural education, participation in study circles and intrinsic values drive efficiency. A positive profitability attitude towards future dairy farming, expressive goals, profitability perception and age restrain efficiency. Decision making aspects found to drive efficiency were checking accounting, paying attention to collected information and information sources such as farm advisors, other farmers and colleagues.

6 Concluding remarks

The common aim of the papers in this thesis was to give empirical evidence of how potential driving and restraining forces at the farm and in its environment contribute to or prevent farm level efficiency. From the synthesis of the literature review above (Section 1.2.3) three themes emerged as fruitful bases to analyze why some farms are efficient and others are not: the overall structure of efficiency, the farm itself and the farmer managerial capacity.

Most significant differences between the efficient and the inefficient farms are found in the two last parts of the research, i.e. in the farm itself and in the farmer managerial capacity. However, analysis of the overall structure of the efficiency also gave important insights. These results showed that especially the ability to minimize costs, i.e. combining inputs in the cheapest way needs to be improved. Further the research showed a weak connection between MCSFs and economic performance. This result is alarming because it shows that actions at the farm to strengthen the MCSFs do not necessarily lead to better economic performance. The results also indicate that the best farms do not have better scores on the MCSFs compared with the less efficient farms. Reasons for this may be that all farms participating in the diary cow recording scheme receive similar managerial advice. The analysis of the overall structure of efficiency also showed that farm size affects efficiency in different ways depending on what type of efficiency is considered. These results have important implications for farmers who plan to expand their farms because the expansion will not necessarily lead to a more efficient farm.

The analysis of the farm itself showed that aspects decided in the long-run strategic management, such as the location of the farm, the farm layout (size of fields and distance to fields), barn type, equipment for forage production and degree of focus on dairy production lay a long-term basis for the farm efficiency and explain differences in efficiency. The micro-social environment is also important, for example discussing the dairy production with someone on a regular basis leads to more efficient farms.

When it comes to the personal factors of the farmer, the results show that more successful farmers have a positive attitude towards dairy farm profits. Furthermore, the more successful farmers value intrinsic values highly, have a high degree of internal locus of control, participate in study circles and have an education in agriculture. The results also show that more successful farmers seek information from farm advisors and colleagues, check the accounting often and pay more attention to gathered information compared to unsuccessful farmers.

Based on these results, how can the farmers be supported to become more efficient? One suggestion that emerges from the research is to focus on developments of the management skills of the farmers. For instance, the farmers need to become better at minimizing costs. This involves developing skills of the farmers such as valuing inputs that are difficult to value (e.g. own labour time and equity financed capital). The results further show that suitable forums for this are forums where the farmers get to learn both from other colleagues as well as from farm advisors. Consequently, the farms can be supported to become more efficient and thus more profitable by organizing combined educational and discussion clubs. The farmers would then not only be able to learn from each other but also inspire each other.

6.1 Opportunities for further research

Having spent four years examining the question of what drives and restrains economic and technical efficiency in dairy farms, I realize that I have still only scratched the surface of the subject. I want to end this introductory chapter by discussing two lines of research that I see as fruitful continuations of my research.

6.1.1 Suggested research line 1: The impact of external factors

To a large extent, I have had an internal perspective to analyzing why some farmers succeed in their farming while others do not. The reasoning has been that internal factors are adjustable by the individual farmer, at least in the long run. However, running a successful farm business, or any kind of business, is dependent on the infrastructure, in the widest sense of the word. Pfeffer and Salancik (1978) offer, as mentioned in the literature review, a resource dependence perspective to describe how firms act and develop. This means that actions of firms are understood by analyzing the context in which they operate. Thus, within this framework, the development of firms is determined by their interdependence with other firms and individuals in the environment. Henrekson (2001) discussed the institutional prerequisites in Sweden in light of entrepreneurship, and concluded that unfavourable prerequisites in Sweden have constrained the founding of small scale firms. A study that illustrates how the environment, in terms of both other firms and individuals as well as institutional prerequisites, affect successful farming would shed further light on what drives and restrains efficient farming. Furthermore, it would be interesting to analyze how efficient and thus successful farms act on the environment in which they operate, compared to the less successful farms. Such a study could involve how the farmer act on a broad range of external interested parties such as creditors, the dairy plant processor, political decisions, consumers, other farmers and farm advisors.

6.1.2 Suggested research line 2: The information needs

As was stressed in Klein et al. (2005), interpreting information from the environment is a foundation to be able to affect one's situation. In business management, information has a substantial impact, not only because it shows the firm results and fulfilments of business goals in other respects, but also because it contributes to the detection of problems, opportunities and threats. When analyzing statistics about size and the number of dairy farms in Sweden a reality is that the farms are becoming larger and larger. Traditionally, dairy farms in Sweden have been one-man or one-woman businesses, or family businesses. However, with the present development towards larger farms, this situation is likely to change, and with that more people are likely to work at the farm. Only the increased need of capital will trigger growth in the number of business owners. Furthermore, larger farms are expected to have employees to a larger extent than smaller ones. With these developments, management will become more important. Questions such as when to adapt to new technology, how to finance the business and how to manage employees are likely to get larger impact in the future. With these developments the ability to act on relevant information both at the farm and in the farm environment becomes more critical. However, given that the usage of the deliberate system is costly (Hogart, 2001) the value of information is limited by the design on information. For instance, Öhlmér and Lönnstedt (2004) concluded that traditional accounting statements are not as useful as verbal interpretations of them, even to farmers with an analytical approach to interpret information. Still, information intended for farm managers, such as accounting reports and reports from the dairy cow recording scheme, is designed to fit analytical thinking processes. The actual information needs at dairy farms have only been studied in a few studies (Huirne et al. 1998; Asseldonk et al. 1999; Lunneryd 2003), but a detailed study that links information use and interpretation of information to the questions of economic and technical efficiency is not found in previous literature. Given this, a suggestion for further research is to analyze the information needs at dairy farms as well as to analyze how information use and interpretation of information differs between the best practice farms and the remaining ones.

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[1] Paper written by me, but published under my maiden name.
[2] Paper co-authored by me, but published under my maiden name.

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