IMPACT OF RISK ON COST AND REVENUE EFFICIENCIES

by

ELIZABETH ANNE YEAGER

B.S., Kansas State University, 2007

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2011

Abstract

This study focused on the inclusion of risk in efficiency measures to determine its impact on traditional efficiency scores. Previous research and theory suggests efficiency scores will be lower under risk and for risk averse individuals. Risk aversion may deter use of new production technologies and production levels may not be as high as under other risk preferences.

Two data sets were used in the analysis. A panel data set of 256 farms from 1993-2010 was used to address the impact of risk measured as variability in outputs and downside risk on efficiency. A separate data set of 258 farms for 2008 was used with a corresponding risk preference score to determine the impact of risk preference on efficiency. The risk preference scores in the sample ranged from 5 to 86 where a smaller value represents stronger risk aversion.

Data envelopment analysis was used to construct a nonparametric efficiency frontier and calculate cost- and revenue-based economic, overall, technical, allocative, and scale efficiency measures. Five inputs: labor, crop input, fuel, livestock input, and capital; and two outputs: crops and livestock were used in the analysis.

The results focused on cost- and revenue-based economic efficiency. They showed that risk did affect average efficiency scores and is necessary to include in efficiency analysis. The average cost efficiency without risk was 0.6763. It increased to 0.7200 and 0.7018 respectively when cost efficiency was adjusted to recognize variability in outputs and downside risk. The average portion of cost inefficiency explained by variability in outputs was 28.06 percent. Downside risk explained 22.66 percent of cost inefficiency. The average revenue efficiency without risk was 0.7611 and increased to 0.8372 and 0.7811 when revenue efficiency was adjusted for variability in outputs and downside risk, respectively. Variability in outputs explained 42.53 percent and downside risk explained 30.58 percent of revenue inefficiency.

The average cost efficiency for the 258 farms was 0.5691 and increased to 0.6043 with the consideration of risk preference scores. The average revenue efficiency was 0.6735 and increased to 0.6987 with risk preference scores. The efficient farms varied across cost and revenue efficiency, and the risk measures used. This lends support to the use of both input-oriented (cost) and output-oriented (revenue) efficiency measures as well as the use of multiple measures of risk.

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Acknowledgements

I would like to thank a number of individuals who helped make this journey a more enjoyable one. I thank my advisor, Dr. Michael Langemeier. Your guidance, support, encouragement and advice were more valuable than you know. Thank you to my committee members, Dr. Vincent Amanor-Boadu, Dr. Jason Bergtold, Dr. Dong Li, and Dr. Amy Hageman, for your helpful suggestions and feedback on my dissertation.

Thank you to Dr. Allen Featherstone for the encouragement and guidance you gave me as both an undergraduate and graduate student in the Department of Agricultural Economics.

Thank you to Dr. John Crespi for believing in me and helping me become a better researcher. I appreciate the comments and suggestions to improve my writing in the early stages of this research.

Thank you to Dr. Jeff Williams for your friendship and support throughout my time at Kansas State University.

Thank you to Dr. Craig Smith and Lee Schulz for your friendship and always pushing me to do my best in coursework and research. Your dedication to this program and your current/future careers is admirable.

Thank you to Dr. Linda Burbidge, Jason Fewell, Dr. Kara Ross, and Koichi Yamaura for your friendship, encouragement, and support.

A special thank you goes to Eric Lowery and my family. I am grateful for your love and support.

Finally, I am thankful for my faith. Without it, I never would have been able to accomplish what I have thus far.

I can do all things through Christ who strengthens me. Philippians 4:13

Dedication

To my parents, G.W. and Betty Ann Yeager, you never doubted I would succeed.

Chapter 1 - Introduction

1.1 Problem Statement

Common concerns in production agriculture often involve risk and uncertainty. What quantities and qualities of goods will result from the inputs used and how much future demand will there be for the end products? Production and yield risk, as well as quantity and quality of outputs that will result from the inputs used are unknown items that affect producers' decision making. Some producers may use more inputs than necessary in attempts to mitigate these concerns. These responses affect their profits and demand to be understood.

As a manager, a farmer attempts to deal with yield and price risk through risk management strategies including diversification, crop insurance, forward contracting, options, or hedging. A formal definition of risk is needed to setup the remaining discussions. The literature offers several definitions many of which do not sufficiently illustrate the differences between risk and uncertainty. Knight (1921, p. 233) provides an often used distinction between risk and uncertainty:

> The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation *a priori* or from statistics of past experience), while in the case of uncertainty that is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique.

In other words, risk is known and can be planned for appropriately and dealt with to remove its impact. Uncertainty, on the other hand, cannot be known.

This study focuses on risk as a measurable negative outcome that is of concern to decision makers. The negative impact of risk is the focus of this research because individuals are likely trying to mitigate risk rather than strive for positive risk. By focusing on risk and addressing its impact on efficiency, more accurate efficiency measures can be obtained. The ability to improve efficiency is overstated when failing to account for risk. Potential improvement is less once adjustments are made for risk.

Why should risk be considered? Perceptions of risk and responses to risk affect production decisions (Robinson and Barry 1987). This results in different cost and revenue functions for risk averse individuals (Coelli, et al. 2005). If it is assumed that most farmers are risk averse and that new technology is risky, then the risk averse farmers would be reluctant to be on the outer frontier of technology adoption (Dillon and Anderson 1971). A risk averse producer will produce less than a risk neutral or risk plunging producer and decrease production levels as perceived risk increases (Robinson and Barry 1987, Ben Jemaa 2007). While risk is a rich topic in the literature, there are still many things that are unknown in terms of its modeling (Buschena and Zilberman 1994). The ability to measure risk and accurately estimate its impacts on a producer's preference is necessary to understand production decisions.

Another important topic in the production literature is efficiency. Efficiency analysis can be used to measure a number of different factors depending on the approach taken. Some of the common efficiency measures are overall, economic, allocative, pure technical, and scale efficiency (Färe, Grosskopf and Lovell 1985). Two approaches will be taken to calculate the efficiency scores: cost and revenue. The cost efficiency measures are more properly defined as input efficiency measures. Input efficiency examines the efficiency of using an input vector to produce a certain output vector with the production technology represented by the inputs. The objective in this scenario is to minimize input costs in the production of a certain output vector (Färe, Grosskopf and Lovell 1985). If a firm achieves this objective, it is overall efficient. An alternative is revenue efficiency or output efficiency. Output efficiency examines the efficiency of an output vector obtainable from a certain input vector with the production technology represented by the outputs. The objective in this scenario is to maximize output revenue from a certain input vector (Färe, Grosskopf and Lovell 1985). A firm achieving this objective is overall revenue efficient.

The importance of efficiency analysis will continue to increase as the amount of land devoted to production agriculture decreases and the demand for food and other commodities increases. New technology may not always be the answer instead better use of the current input mix may result in an increase in outputs without requiring more inputs. The increased importance of efficiency is another reason why a more accurate measure is desired.

The nonparametric approach to measuring efficiency is especially attractive because it does not impose restrictions on the underlying technology set that would be imposed if a parametric approach was used (Chavas and Aliber 1993, Featherstone, Langemeier and Ismet 1997). This attractive feature is also an issue in the fact that heterogeneity among the firms in the sample is not introduced in the model instead only information on inputs, outputs, and prices are typically utilized in the estimates. The introduction of risk preferences would allow for heterogeneity among the farms.

The nonparametric approach is extremely flexible and useful for both calculating and decomposing efficiency measures (Färe, Grosskopf and Lovell 1985). The calculated efficiencies represent upper bounds to the true efficiencies. The alternative parametric approach requires the selection of a representative technology. A fairly flexible parametric approach must be used because the imposition of the wrong functional form will likely affect the resulting efficiency measures adversely. The parametric approach does have favorable characteristics. This approach accommodates noise, measurement error, and exogenous shocks, and therefore does not attribute these items to inefficiency.

The current study will focus on the nonparametric approach. This study improves upon traditional nonparametric efficiency studies that only use input and output data by including additional risk measures and risk preference in the efficiency estimation. The relationship between risk and efficiency is an important area of research because, despite the fact that both topics have received considerable attention, the literature has failed to sufficiently link them together. If some farmers are risk averse, then they may be choosing a level of production that is not viewed as optimal (efficient) by standard efficiency measures. Resources may be allocated to counteract risks perceived, so it is important to determine if they are being allocated efficiently (McKenna 1986). Therefore, a method needs to be utilized that can measure efficiency while considering the impacts of producers' risk. The measurable risk can be addressed and properly minimized using risk management techniques. The risk adjusted efficiency measures will more accurately illustrate the true inefficiency and the actual improvements that could be made.

In this study, traditional efficiency scores and risk adjusted efficiency scores will be measured. It is reasonable to presume the scores will differ. Likely there will be more firms deemed efficient once the risk measure is included in the estimation. The end goal is that pieces of this project can be dispersed through research outlets to modify how efficiency analysis is performed and provide a missing connection in the literature. In the private sector the results should be beneficial for financial institutions, lenders, and financial consultants. If traditional efficiency measures have been used as part of their criteria for financing, updated measures adjusted for risk may be used instead. Interesting extension applications may be derived from this work if the efficiency scores do change with the inclusion of risk. The amount by which risk averse producers are able and willing to change production decisions to improve efficiency is likely different. This may be an indicator that in fact more farms are producing efficiently than previously thought. Also, because risk is something that will always be inherent in production agriculture and other businesses, being able to consider risk in efficiency analyses will improve the accuracy of benchmarking across years.

1.2 Objectives

The overall objective of this study is to determine the portion of standard measures of inefficiency that can be attributed to risk. The specific objectives are as follows: determine reasonable proxies for risk and risk preferences, use the proxies in nonparametric efficiency analysis for input- and output-based efficiency measures, and examine differences observed in efficiency scores.

The existing literature on risk, stochastic frontiers, nonparametric efficiency, risk preferences, and acreage response will be discussed in the next chapter to determine the best methods to link risk and efficiency together and to strengthen the hypothesis that an individual's exposure to risk does affect their efficiency as currently measured. The inclusion of risk in efficiency measures will allow for a more accurate representation of the efficiency facing the firm.

This study fills a major gap in the existing literature by examining efficiency with the inclusion of two risk measures and a risk preference measure for two samples of Kansas farms. This study contributes to the existing literature by outlining a framework for including variables that impact the ultimate efficiency of a farm but are fundamentally out of the decision maker's control. This study illustrates the portion of inefficiency attributed to risk and finds traditional efficiency measures overstate the potential increases in efficiency. The characteristics of the efficient farms with and without the inclusions of risk are documented and compared to the average for the farms in the sample.

Chapter 2 - Literature Review

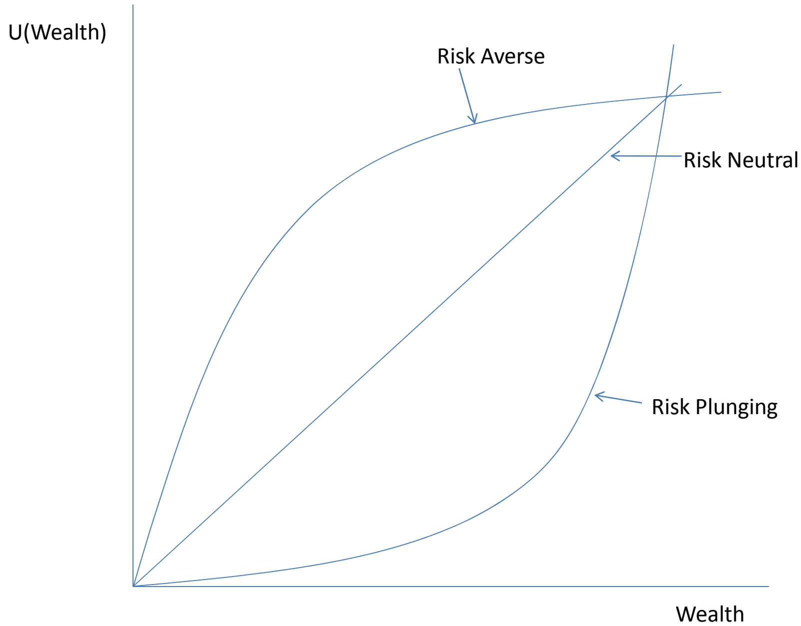
This section will provide an overview of relevant literature in the risk and efficiency fields. Five subsections: risk, stochastic frontier analysis, nonparametric efficiency analysis, risk preferences, and acreage response are presented. Each subsection discusses studies in chronological order. In cases where a piece may fit into more than one subsection, a subjective placement was made based on where the largest contribution for this piece of research was made.

2.1 Risk

Historically, the risk literature goes back several centuries. "Risk and its management in agriculture have been of concern to policy makers since at least the time of Joseph in Egypt" (Patrick and DeVuyst 1995, p. 1). Scholarly work dates back to the research by Bernoulli (1738). However, an appropriate place to start is with Arrow and Pratt and their contributions in the last 50 years or so. Various terms are used for an individual that prefers risk rather than a certain income. Some literature uses risk preferring, risk loving, or risk plunging. To avoid confusion, risk plunging will be used to identify risk preferring, risk loving, or risk plunging in the dissertation below.

Pratt (1964) and Arrow (1965) independently identify a measure of an individual's local or absolute risk aversion. Levy and Levy (2002) provide a comparison of the work done by both Arrow and Pratt. Absolute risk aversion is still used today in many studies and is calculated by dividing the negative of the second derivative by the first derivative of the utility function. A positive first derivative of the utility function indicates that more income or wealth is preferred to less. A negative second derivative of the utility function indicates risk aversion. The rationale for using this measure comes from representing risk aversion by the concavity of an individual's utility function. However, Pratt (1964) notes that neither the first nor second derivative are a meaningful measure by themselves for measuring concavity. The degree of concavity, a measure of the degree of risk aversion, can be captured by the second derivative of the utility function. The first derivative of the utility function is a measure unique to the preference ordering and is used to normalize the absolute risk aversion measure (Moschini and Hennessy 2001). The sign of the absolute risk aversion measure is used to determine if an individual is risk averse (positive), risk neutral (zero), or risk plunging (negative). Risk aversion implies that a lower guaranteed income with certainty is preferred to the expected value of an activity in order to avoid risk. Risk neutrality implies indifference between taking the risk and receiving the expected value. Risk plunging implies an individual prefers the risky alternative to a guaranteed income. Figure 2.1 illustrates the utility functions for risk averse, risk neutral, and risk plunging individuals. Notice the risk neutral individual has the same additional value of utility measure for each additional increment of wealth. The risk averse curve indicates that for each additional increment of wealth the additional value of utility becomes increasingly smaller. The risk plunging curve is increasing at an increasing rate so every additional increment of wealth results in an increasingly larger increase in utility.

Figure 2.1: Risk averse, risk neutral, and risk plunging utility curves



Brown, Harlow, and Tinic (1988) examine investors' responses to unanticipated favorable and unfavorable events and whether the reactions to these events are efficient for the 200 largest firms in the Standard and Poor's 500. Three propositions are tested for the uncertain information hypothesis: "(i) stock return variability will increase following the announcement of any major unanticipated event; (ii) the average price response following negative events will be positive and those following positive events nonnegative; and (iii) on average the postevent price changes will be larger for a sample of unfavorable events than for favorable events if absolute risk aversion is decreasing, and the same if it remains constant" (Brown, Harlow and Tinic 1988, p. 360). It is found that the risk measure chosen does not have a significant impact on the outcome. Using total variance, beta, or diversifiable risk, the largest uncertainty is observed for stocks that had the biggest increases or decreases in price.

Patrick and DeVuyst (1995) provide an overview of farm mangement research and extension programs related to risk. They argue that although there has been an increase in the research related to risk the information that is being shared with producers and through extension programs is not keeping up. Common methods to determine a risk efficient set are mean-variance (EV), simulation models, stochastic dominance, and discrete stochastic programming. Stochastic dominance can be used as an alternative to the EV method and does not restrict the utility function to a specific functional form. Patrick and DeVuyst (1995) analyze software tools and packages available for farm management decisions. These include CROPSTEM, RESEED, BEFEEDER, Cash Flow Planner, Purdue's Analysis series, FINPACK, the Agricultural Risk Management Simulator (ARMS), Budget Enterprises and Analyzing Risk Plus Financial Statements (BEAR Plus), Integrated Farm Financial Statements (IFFS) Risk Analyzer, and Top Management Farm Business Simulator (TOPRISK). It is suggested that a tool that provides a simple projection of the effect of production and marketing decisions is more valuable than a complicated and data intensive analysis. An excuse for the fact that "risk is ignored in over 30% of the risk-related problems with which extension specialists work" is that most of the risk analysis tools that are available are too complex for producers to use (Patrick and DeVuyst 1995, p. 8). Other reasons for the lack of risk material presented in extension programs could be because it matters more to researchers and extension personnel than it does to the actual producers. "Farmers are not concerned with the 'optimal' decision in an abstract situation such as is typically assumed in research, but rather what is the best decision for them in their specific situation" (Patrick and DeVuyst 1995, p. 9). Additionally, risk may not be as large of a concern to producers because of the cost to obtain additional information. Producers might not value information regarding risk delivered through extension workshops or software programs as higher than the cost of obtaining the information. Therefore, one avenue towards increasing producers' interest in risk and extension workshops focusing on risk would be to lower the costs to producers and strengthen the argument of how valuable the information is to management decisions.

Pannell, et al. (2000) provide their perspective on including risk in modeling farm level decisions. They use published results from previous studies to argue that including risk or allowing for risk aversion rather than risk neutrality in models does have an impact. However, the authors warn about spending too much time assessing the importance of risk or using large risk aversion coefficients because the impact may be very small. They are concerned with the risk management research not being directly applicable to farmers. While this may be a concern, this study is not meant to provide recommendations of changes to farmers, rather the goal is to explain the differences already present between individual farms.

Moschini and Hennessy (2001) stress the importance of understanding risk and its impact on agricultural production. They discuss the expected utility model and modeling production decision risk. Important to this research is their analysis of previous empirical studies. A common concern is that survey work and interviews are only reliable when they capture the preferences that would be revealed in actual decision making and the cost of these methods often makes them infeasible. Using observed supply and input demand to compute risk preferences is not a perfect solution either as differences may be due to other effects besides risk preference. The authors conclude by discussing methods that are available to help manage risk and increase the well-being of risk averse individuals. Methods suggested are price-contingent contracts (forward, futures, and options), crop insurance contracts, and portfolio diversification.

Abdulkadri, Langemeier, and Featherstone (2003) estimate the risk attitudes of dryland wheat, irrigated corn, and dairy producers in Kansas using a nonlinear mean-standard deviation approach. Parameters to estimate the risk attitudes are estimated using a system of equations including the production function, cost function, and first-order condition of the utility function. Regression analysis indicates gross farm income has a negative effect on absolute risk aversion and a positive effect on the relative risk aversion for the three enterprises examined. Dryland wheat and dairy producers are characterized by increasing absolute and relative risk aversion. Irrigated corn producers are characterized by constant absolute and increasing relative risk aversion.

Turner (2003) examines the effect of perceived house-price risk or volatility on homeownership and housing demand conditional on homeownership. The house-price volatility coefficient was negative and significant at the 0.01 level for all results presented. This reflects a 4 percent decrease in homeownership and housing demand for a 100 percent increase in projected volatility. This study does not examine efficiency, but it is an indicator of the importance of including risk in models evaluating decision making or production decisions. It also provides a framework for using a variability measure to predict future risk or volatility.

Alghalith (2006) tests for risk neutrality using a model that allows for both price and output risk. Under the incorporation of output risk, the commonly used duality theory and the indirect utility function approach can no longer be used. The results found using U.S. manufacturing data were consistent with theory: an increase in price or output riskiness reduces optimal output.

2.2 Stochastic Frontier Analysis

This subsection of literature focuses on the use of a parametric or stochastic frontier approach. These studies have all attempted to include a risk measure usually a measure of variance in an input, output, or price. A major issue common with the use of stochastic frontiers is imposing a functional form *a priori* which may result in potential misspecification.

Just and Pope (1978) focus on the importance of specifying production functions in a way that takes risk considerations into account. At the time of their paper, Cobb-Douglas production functions were the norm and the authors argue that this functional form incorrectly imposes the restriction that inputs have a risk-increasing effect on the outputs. Just and Pope argue that increasing, decreasing, or constant marginal risk should all be considered and allowed in a modeling approach. It is necessary to allow for increasing, decreasing, or constant marginal risk because not all inputs to production have the same impact on the variance of production. Some inputs (i.e., land, fertilizer, chemicals) may increase variance. Other inputs (i.e., pesticides, irrigation, frost protection) may decrease variance of production. The authors outline eight postulates that an appropriate functional form should satisfy and provide a theoretical analysis for the general functional forms that satisfy the postulates.

Just and Pope (1979) add upon their previous work by continuing to justify that traditional econometric production studies are not properly considering the impact of increased inputs on the variance of production. They argue that many functional forms in addition to the Cobb-Douglas incorrectly assume that if an input has a positive effect on output, then it has a positive effect on the variability of output. They provide both a theoretical and empirical approach that considers the effects of input on the mean of output and on the variance of output separately. They use Cobb-Douglas and Translog functional forms to examine corn and oat production response to fertilization. Results indicate fertilizer increased yield variance, but the marginal variance contribution is much smaller than traditional approaches indicated. Therefore, this study supports the importance of considering risk measures in production estimation and one way to do that is by considering the effect of input use on the variance of output.

Coyle (1992) develops duality models under risk aversion and price uncertainty within a linear mean-variance framework. Coyle's work attempts to overcome the criticism that applied duality theory cannot incorporate producer risk aversion and uncertainty. Standard duality theory typically assumes risk neutrality. With a linear mean-variance utility function, price uncertainty duality models can be estimated with few problems. Price uncertainty measured as price variability, rather than yield uncertainty is Coyle's primary focus because of the use of aggregate, annual time-series data from 1961-85 for Manitoba, Canada. Coyle estimates a generalization of a normalized quadratic dual profit function using the seemingly unrelated regression method for two outputs (crops and livestock) and three inputs (labor, other variable inputs, and capital services). The inclusion of price uncertainty (price variances) results in significant own price effects that were not significant in the original model. Output supply changed as a result of including the variances and the coefficients were significant. The changes were small, but the author believes these models are an improvement over the standard models.

Kumbhakar (1993) measures production risk and (relative) technical efficiency using panel data for 37 Swedish dairy farms from 1986-1988. The study is motivated by the fact that despite risk being addressed in detail in theoretical studies, few empirical studies have included risk. A multi-step procedure is used to estimate the parameters of the model. Risk is specified as a function of the inputs and appears multiplicatively within the production function. Kumbhakar uses a translog production function incorporating risk through the inputs and introducing technical efficiency. Relative efficiency scores were calculated for each firm for each of the three years. Unfortunately, comparisons cannot be made in regards to the inclusion versus exclusion of risk because results are only reported for the efficiency estimation with risk. The results indicated the farms were generally efficient with the averages in the three years being

92.45 percent or higher. The lowest efficiency score for any firm during the three year period was 80.29 percent.

Coyle (1999) develops a dual indirect utility function for both constant absolute risk aversion and Just-Pope technology and for a more general case of non-constant absolute risk aversion and a general technology. The Just-Pope production function models output equal to nonstochastic input levels and a stochastic weather variable. Under constant absolute risk aversion, the nonlinearity did not pose a strong problem. However, the greater nonlinearity in non-constant absolute risk aversion causes difficulties in estimation. Either way, the restrictions placed on the models are quite limiting. The study uses the same data as Coyle (1992) and finds similar results. The author concludes that the model with uncertainty may be more appropriate than other duality models because it results in more significant coefficients.

Ben Jemaa (2007) hints at many of the issues this dissertation hopes to address. He argues that farmers should be concerned about technical efficiency as they strive to reach the "best practices" under available technology. A dual model, with strong assumptions regarding preferences and technology, was utilized. One widely agreed upon fact is that risk averse producers will produce less than risk neutral producers and the risk averse producer will decrease output as perceived risk increases. Ben Jemaa uses weather variance as a measure of risk for Tunisian cereal producers from 1983-2005. The results indicate uncertainty about weather conditions does influence producer decisions by reducing the output supply of wheat. Ben Jemaa estimates an absolute risk aversion coefficient for the northern and southern regions of Tunisia and found the coefficient for the south to be five times greater than the north. The coefficients for both regions are significant. The major self-addressed criticism of the study is the use of aggregate rather than farm-level data.

2.3 Nonparametric Efficiency Analysis

The nonparametric or nonstochastic method of estimation does not impose a functional form on the production frontier and is less prone to misspecification (Färe, Grosskopf and Lovell 1994). Data envelopment analysis (DEA) is one method for estimating efficiency and constructs a frontier based on the "best" performers in the sample.

Berg, Førsund, and Jansen (1992) calculate efficiency scores and Malmquist indices of productivity growth for Norwegian banks that survived the deregulation of the banking industry in Norway during the 1980s. One contribution made by the authors is including loan losses as an indicator of risk exposure in the output vector. This was included because productivity growth may change as banks are exposed to more risk from poor loan evaluations. Results suggest that the loan losses have a very small effect on efficiency scores.

Chang (1999) incorporates risk as a joint but undesirable output into efficiency measures in his evaluation of financial institutions in Taiwan. He argues that banks with excessively risky loans might be considered efficient compared to banks that spend resources to guarantee they have higher quality loans. Thus, inefficiency may be miscalculated unless a risk measure is included. Chang uses three different risk indicators (nonperforming loans, allowance for loan losses, and risky assets) separately to determine the impact of risk on the efficiency measures. Chang uses the nonparametric approach and acknowledges that typically outputs are "goods" but outputs may also be "bads" as in the case of risk (p. 904). Therefore, the goods and bads need to be considered asymmetrically in the efficiency measures. The output vector is divided into two subvectors to account for the vector of goods (desirable outputs) and the vector of bads (undesirable outputs). Results indicate that the inclusion of a risk measure as an output increases the number and percentage of firms that are technically efficient. Chang did not look at any other efficiency measures in his study.

Färe, Grosskopf, and Weber (2004) use directional distance functions to measure profit efficiency and its components, technical and allocative efficiency, for a sample of U.S. banks. The main contribution of their work is the inclusion of a risk-based capital constraint and a leverage constraint to examine the impact on profit efficiency. The need arises because managers may be pursuing less risk rather than strictly higher profits, so it is important to consider the impact of capital structure on inefficiency. Results of the study indicate the impact of risk-based capital standards on allocative and profit inefficiencies is less when capital constraints are included in the estimation.

Färe and Grosskopf (2005) use index functions to address the issue of undesirable outputs, specifically in environmental quality scenarios. Production of a desirable output is sometimes linked to an undesirable output. Because the undesirable output is typically not marketed, a firm that chooses to reduce that output is not credited with the reduction. This is problematic because under common productivity and efficiency measures, the firms that are able to reduce the undesirable output (e.g., pollution) appear to be less efficient than firms who choose not. Färe and Grosskopf (2005) did not address risk in their study, but essentially the issue is similar in the fact that most efficiency studies are not taking risk into account when comparing the efficiency levels of competing firms. It is plausible that risk or the variability in production could be included as a "bad" output.

Blancard, et al. (2006) examine the differences between profit functions with and without a credit constraint using a panel of French farmers. They use nonparametric technologies that do not impose a functional form and allow for inefficiency to measure technical, allocative, and financial efficiency. The model uses credit constraints to examine technical and allocative efficiency. A firm that is bound by a credit or expenditure constraint is deemed financially inefficient and the allocative inefficiency may be attributed to financial reasons. A firm that is allocatively inefficient but not constrained by expenditures is financially efficient and the allocative inefficiency is attributed to other causes. The authors find that in the long-run, financial constraints explain about 49 percent of overall efficiency. They also find the credit constraint to be binding for 67.2 percent of the firms in the short-run and 99.7 percent of the firms in the long-run. Additionally, the authors employ a Tobit model to try and explain the differences in the observed financial inefficiency results.

2.4 Risk Preferences

Individuals are characterized at times by their preferences towards risk: averse, neutral, or plunging (Arrow 1965, Pratt 1964). A number of researchers have attempted to elicit risk preferences through survey and experimental approaches.

Halter and Mason (1978) explain a method of estimating utility functions using survey questions. They test their method using a sample of 44 Oregon farmers and obtain risk preferences based on their survey responses. The interesting aspect of this study was the regression analyses used to determine statistically significant characteristics given risk preference. The authors find age, education, and percentage of land ownership all influence risk preference. Farmers with a larger percentage of land owned tend to be risk averse. Farmers with higher levels of education and older farmers are more risk plunging. However, the relationships are highly nonlinear and the interactions between the independent variables greatly impacts the risk preferences. A larger sample could be more encouraging, but it appears based on this study that a simple calculation of risk attitude based on producer characteristics is not sufficient without considering the interaction of all the characteristics included in the model.

Young (1979) reviews common risk preference measurement methods including the direct elicitation of utility functions, experimental methods, and using observed input demand and output supply behavior. Issues with previous empirical studies using these methods are the fact that few producers have actually been interviewed, the specification of the utility function greatly impacts the results, surveys and interviews are expensive to conduct (especially in person), and most of the samples are not representative of the industry. Some of the models restrict the possibility of risk neutral or risk plunging attitudes even when the data indicate the producer is not risk averse. While still restrictive, the indirect method of capturing risk preferences seems to be preferred. One way to do this is to examine the difference between the expected marginal value product of an input and the nonstochastic marginal factor cost of the input and divide by the marginal contribution to risk of additional input use to find the producer's local risk aversion coefficient. This seems to be a promising method, but obtaining the marginal contribution of risk estimate is difficult and can introduce additional errors along with the issue of imposing a functional form. The results of Young (1979) are encouraging for this study. The technique used in this study is related to the indirect method.

Hoag and Keske (2010) describe two methods of eliciting risk preferences from individuals. One method uses a psychology-based quiz to gather information on how respondents might react to different hypothetical situations. The other method uses a financial approach to determine how respondents make choices that replicate risk trade-offs in terms of financial gains and losses. Using a similar approach to the psychology-based quiz, Pope (2009) surveys Kansas Farm Management Association members with a whole-farm analysis and cowherd in 2008. Five questions in the survey are related to risk: how a respondent's neighbor would describe their risk taking behavior, retained ownership strategies, best and worst case calf return strategies, and questions related to investing in an innovative business with the chance for a large gain, but a significant chance of loss. Possible responses are ordered from risk averse to risk plunging. There are 272 respondents to the questions and risk preference is based on the responses given. The scores are determined by assigning a "1" to "a", "2" to "b", etc. and squaring the scores for each question. The scores can range from 5 for an extremely risk averse individual up to 113 for a risk plunging individual. The scores in the sample range from 5 to 86 (Frasier-Pope, Schroeder and Langemeier 2010).

2.5 Acreage Response

The literature on acreage response is examined because of the increased interest in risk and the supply response of commodities to risk. The majority of papers considered below are interested in risk or the lack of risk as a result of government programs. The inclusion of price or yield risk variables measured as the variance and/or covariance strengthens the argument and necessity that risk should be included in efficiency estimation.

Bailey and Womack (1985) examine acreage response for wheat in five production regions in the U.S. The authors assume wheat yield to be a source of risk because at the beginning of the production period input prices are known but output prices and yields are unknown. The risk variable has the predicted negative sign but is not significant in any of the five regions. However, the government policy variable which may be indirectly related is significant in almost every region.

Chavas and Holt (1990) develop an acreage response model for corn and soybeans including a "risky" revenue variable. Revenue is risky because output prices and yields are unknown when production decisions occur. Price support programs place a floor under the market price which must be considered when investigating the influence of government programs on acreage decisions. The output price and resulting revenue are less “risky” with the price constraints. Soybean acreage responds to risk more than corn acreage possibly because government intervention has historically been less in the soybean market. The U.S. producers included in the study are not characterized by constant absolute risk aversion. Chavas and Holt (1990) also include a wealth variable in estimation and find policies may be better targeted to low income producers.

Duffy, et al. (1994) observe the direct and indirect impacts of government programs on the supply response of corn, cotton, and soybean acreage. Traditional farm programs have provided price guarantees in exchange for limitations on planting or harvest. This affects the risk of production by impacting the mean expected return and variance of return. Duffy, et al. (1994) find that price variability has little effect on corn and cotton which have been recipients of more government programs than soybeans. It is also found that the risk variability of soybeans affects the acreage of all crops. This indicates a shift from the riskier crop to program crops that are designed to have less price risk.

Liang, et al. (2011) examine the supply response of corn, cotton, and soybeans to price and yield risk. The authors argue ignoring the price and yield risks may result in not accurately capturing the variable nature of crop production. To capture risk, the variance and covariance of revenue for the three crops are included in the model. Results indicate an increase in acres planted when revenue and the variance of revenue increase.

2.6 Justification for This Study

The previous literature reviewed above provides a justification for this study. There have been several attempts to add a risk or a bad output to traditional efficiency measures, particularly in the banking and environmental literature. This is not a common practice in the agricultural economics literature, possibly due to the difficulty in obtaining an appropriate measure of risk and/or data limitations in general. Many of the previous studies were done using a cross-sectional data set or an aggregated time series and not a panel data set which would allow for a more meaningful study.

This study will add to the literature on efficiency by considering multiple risk measures and using two data sets. Unlike the previous literature that has attempted to solicit either direct or indirect perceptions of risk from managers, this study will further contribute by using variability in outputs and downside risk as risk measures. A risk preference score will be used in a separate data set. Additionally, the model used in this study will be less limiting than previous models because no functional form is imposed.

Variability is measured by the standard deviation of the outputs in the previous 10 years and included as a bad output/nondiscretionary input. Downside risk is measured as a weighted summation of the net farm income below the amount needed to pay for unpaid labor during the prior 10 year period. The inverse of the risk preference score collected by Pope (2009) is also used as an input in the efficiency calculation in the same way as the inclusion of the other risk constraints to identify how a producer's risk preference impacts their efficiency score.

Chapter 3 - Theory

This chapter adds to the motivation of this study and provides a justification for the methods used in the following chapters. The first section discusses the theoretical framework of cost and revenue functions followed by cost and revenue efficiency. The risk section is divided into two subsections. In the final section the link between efficiency and risk is examined. This chapter is not intended to cover every aspect of these important topics but to provide a background on the theory and a resource that highlights the different topics.

3.1 Cost and Revenue Functions

3.1.1 Cost

Efficiency cannot be accurately defined without an initial introduction to production theory. Production economics attempts to find the outer frontier available for transforming inputs into outputs. The theoretical assumptions of production economics provide a foundation for estimating the unobservable benchmark or frontier of optimal production.

A set of assumptions for a single-output production function are outlined below. The restrictions are almost identical for the multi-output case. These assumptions do not allow for technical inefficiency and as written below assume an econometric estimation under a functional form. If we assume $y=f(x)$ then, following Chambers (1988, p. 9):

Properties of f(x):

1. (a) if $x' \geq x$, then $f(x') \geq f(x)$ (monotonicity);

   (b) if $x' > x$, then $f(x') > f(x)$ (strict monotonicity);

2. (a) $V(y) = \{x: f(x) \geq y\}$ is a convex set (quasi-concavity);

   (b) $f(\Theta x^0 + (1- \Theta)x^*) \geq \Theta f(x^0) + (1- \Theta)f(x^*)$ for $0 \leq \Theta \leq 1$ (concavity);

3. (a) $f(0_n) = 0$, where 0_n is the null vector (weak essentiality);

   (b) $f(x_1, \ldots, x_{i-1}, 0, x_{i+1}, \ldots, x_n) = 0$ for all x_i (strict essentiality);

4. the set $V(y)$ is closed and nonempty for all $y > 0$;

5. $f(x)$ is finite, nonnegative, real valued, and single valued for all nonnegative and finite x;

6. (a) $f(x)$ is everywhere continuous; and

   (b) $f(x)$ is everywhere twice-continuously differentiable (Chambers 1988, p. 9).

The cost function is used to determine how producers determine the optimal inputs to use (Coelli, et al. 2005). This study will use multiple inputs and outputs with input prices taken as given. Following Chambers (1988, p. 50), the cost function is defined as $c(w,y) = \min_{x \geq 0}\{w{*}x: x \in V(y)\}$ where w is a vector of positive input prices, x is the input vector, y is the output vector and $V(y)$ is the input requirement set. If the production function satisfies the properties listed above, the cost function will satisfy the following properties.

Properties of c(w,y):

1. $c(w,y) > 0$ for $w > 0$ and $y > 0$ (nonnegativity);
2. if $w' \geq w$, then $c(w',y) \geq c(w,y)$ (nondecreasing in w);
3. concave and continuous in w;
4. $c(tw,y) = tc(w,y),\ t > 0$ (positively linearly homogenous);
5. if $y \geq y'$, then $c(w,y) \geq c(w,y')$ (nondecreasing in y); and
6. $c(w,0) = 0$ (no fixed costs) (Chambers 1988, p. 52).

The cost function corresponds to the input-oriented efficiency measures and is chosen because the input prices are taken as given and the firm is choosing the level of inputs to produce the outputs. The input-oriented technical efficiency measure addresses the question of how much input quantities can be proportionally reduced without changing the output quantities produced (Farrell 1957). Alternatively, the revenue function and output-oriented efficiency measures can be implemented. These measures identify how much output can be produced with the current input quantitites. The input-oriented and output-oriented measurements are equivalent when constant returns to scale exist (Coelli, et al. 2005).

3.1.2 Revenue

The revenue function does differ between the single-output and multi-output cases. In the case of one output, no choice needs to be made because maximizing the value is simply producing at the point on the production frontier that corresponds with the input set. A choice arises in the multi-output case because an input bundle can produce a variety of outputs.

Following Chambers (1988, p. 255), the producible-output set is defined as $Y(x) = \{y:(x,y) \in T\}$ where x is the input vector, y is the output vector and T is the production possibilities set.

Properties of Y(x):

1. $Y(x)$ is nonempty and closed;
2. if $y \in Y(x)$, $y^1 \leq y$, then $y^1 \in Y(x)$; if $x^1 \geq x$, then $Y(x^1) \supseteq Y(x)$;
3. $Y(x)$ is convex;
4. $Y(x)$ is bounded from above for finite x; and
5. if $y \geq 0$, $y \notin Y(0_n)$; $0_m \in Y(x)$. (Chambers 1988, p. 256-257).

If $Y(x)$ follows the properties above, the revenue function, $R(p,x) = \max\{p*y:y \in Y(x), p > 0\}$, where p is the input price and all other variables remain as previously defined, satisfies the following properties.

Properties of R(p,x):

1. $R(p,x) \geq 0$ (nonnegativity);

2. if $p \geq p^1$, then $R(p,x) \geq R(p^1,x)$ (nondecreasing in p);
3. $R(tp,x) = tR(p,x)), t > 0$ (homogeneous);
4. $R(p,x)$ is convex and continuous in p; and
5. if $x^1 \geq x$, then $R(p,x^1) \geq R(p,x)$ (nondecreasing in x). (Chambers 1988, p. 263).

The next section provides a description of the cost and revenue efficiency measures that correspond with the cost and revenue functions outlined above.

3.2 Cost and Revenue Efficiency

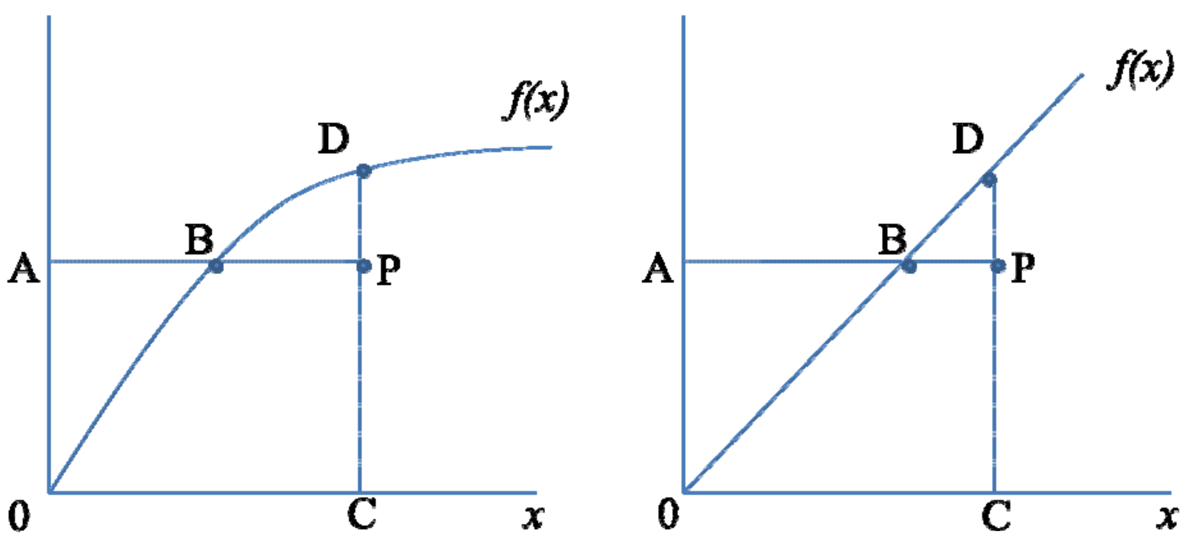
The efficiency of a firm is an index of observed and desired performance (Färe, Grosskopf and Lovell 1985). Most production studies automatically assume that producers are efficient when often this is not the case. The study of inefficiency is necessary to gain further insight into production outcomes and observed differences among producers.

Both input and output efficiency measures are examined. Input efficiency measures the efficiency of an input vector at producing a fixed output vector (Färe, Grosskopf and Lovell 1985). The output vector is taken as given and does not change for the firm. Therefore, input efficiency measures correspond to a cost minimization problem. It is assumed that as firms choose the mix of outputs used in production, the inputs chosen are based on their minimum production cost. Output efficiency measures the efficiency of producing an output vector obtainable from a fixed input vector. The input vector does not change for the firm similar to a revenue maximization problem. The revenue maximization problem is less commonly used in production economics (Coelli, et al. 2005). It is an important addition to this study and may be more relevant than previous studies have given it credit for when considering decision making in a risky environment. A firm may realize it is not minimizing costs when considering risk but maximizing revenue. Similarly, it may not be maximizing revenue but minimizing costs because of the incorporation of risk.

Technical efficiency under the input-oriented approach measures the amount by which all inputs could be reduced while maintaining the same level of output (Coelli, et al. 2005). Input price information is not required in the calculation of technical efficiency. A firm is technically efficient if producing on the production frontier. Alternatively, technical efficiency under the output-oriented approach measures the amount by which all outputs could be increased while maintaining the same level of inputs (Coelli, et al. 2005). A comparison is shown below in Figure 3.1. The example utilizes one input, *x*, and one output, *q*, with nonincreasing returns to scale in panel (a) and constant returns to scale in panel (b) represented by the frontier *f(x)*. An inefficient firm is operating at point P. The input-oriented technical efficiency is equal to the ratio AB/AP, and the output-oriented technical efficiency ratio is equal to CP/CD. The measures are only equivalent under constant returns to scale.

Figure 3.1: Input- and Output-Oriented Technical Efficiency Measures and Returns to Scale (Coelli, et al. 2005, p. 55)

(a) Nonincreasing Returns to Scale (b) Constant Returns to Scale



Cost efficiency and revenue efficiency, also known as economic efficiency for each of the approaches, is the product of allocative and technical efficiency. Allocative efficiency in input selection selects the mix of inputs that results in a given quantity of output for the minimum cost. Allocative efficiency in output selection determines the mix of outputs from a given input vector for maximum revenue. Scale efficiency is a measure used to determine if the firm is operating at the optimal size. The product of technical, allocative, and scale efficiencies is overall efficiency. Overall efficiency is a long-run efficiency measure because it is comparing the observed cost or revenue to the minimum cost or maximum revenue with constant returns to scale technology. The cost and revenue efficiencies are short-run efficiency measures because of the use of variable returns to scale technologies. All efficiency scores can take a value between 0 and 1 and are only comparable within the sample studied. The following chapter provides information on the methods used to calculate the efficiencies.

3.3 Risk

It is necessary to study risk in order to understand the production decisions made by a firm. A firm under certainty will maximize profit at a different point than a firm operating in a market plagued by risk (Robinson and Barry 1987). Knight (1921) defines risk to be a known distribution of outcomes for a group of instances that can be planned for and dealt with appropriately while uncertainty is unique cases that do not belong to a group and the distribution of outcomes is unknown. Robinson and Barry define risk as an “uncertain event that alters the decision maker’s well-being” (1987, p. 14). Despite the differences in definitions, the focus is essentially on the same thing: for risky events, we know either *a priori* or *a posteriori* the distribution of the outcomes and how the outcomes affect the decision maker’s involved in the situation.

The shape of individual's utility curves can be used to explain risk preferences or reactions to situations under risk (Arrow 1965, Pratt 1964). Risk aversion (concave utility function) implies that a lower guaranteed income with certainty is preferred to the expected value of a gamble in order to avoid risk. Risk neutrality (linear utility function) implies indifference between taking the risk and receiving the expected value. Risk plunging (convex utility function) implies an individual prefers the risky alternative to a guaranteed income (see Figure 2.1).

Decision making under risk has been modeled a number of ways. Arguably, the most well-known portfolio selection tool is expected value variance or mean-variance analysis. It is a method for ordering choices based on the expected value and variance of the outcomes (Markowitz 1952). Target MOTAD (minimization of total absolute deviations) is another tool that will reach similar results to the mean-variance under normal distributions and may be more appealing when distributions are skewed (Tauer 1983). Target MOTAD models generate second-degree stochastic dominance results using a linear programming algorithm. Value at risk (VaR) is a single summary measure usually reported as a dollar amount based on historical data or projections that represents the most a firm could expect to lose at a given confidence level (Linsmeier and Pearson 2000). While VaR is a useful tool, it is unlikely that decisions are made solely from one number. It fails to consider losses under very unlikely events, however, stress testing can be implemented to examine worst-case scenarios (Linsmeier and Pearson 2000).

The sub-sections below illustrate two important approaches to dealing with and modeling risk. Both mean-variance and downside risk are introduced to provide more information on the justification and history of their use.

3.3.1 Mean-variance

Arguably the most common measure of risk in business and economics is the mean-variance or expected value (E) variance (V) approach. EV efficient sets of choices offer the minimum variance for alternative levels of expected returns (Robinson and Barry 1987, Markowitz 1952, Samuelson 1970, Tobin 1958). In other words, if outcome A has an expected value greater than or equal to outcome B, and the variance of outcome A is less than or equal to outcome B, with at least one inequality, then A is preferred to B (Hardaker, et al. 2004). The EV model is analytically appealing because of the relationship between risk and variability, the ability to conduct analysis with a relatively small amount of information (only data on the mean and variance of outcomes is necessary), and the consistency with expected utility models. Conditions for the use of the EV approach are listed below: "(1) quadratic utility, (2) normality, (3) choices involving a single random variable, and (4) choices involving linear combinations of the random variable" (Robinson and Barry 1987, p. 72).

Quadratic utility implies increasing absolute risk aversion because marginal utility becomes negative past some outcome (Robinson and Barry 1987). Few variables have a symmetric distribution and can take values spanning from negative to positive infinity as implied by normality. Most choices do not involve only one random variable leaving condition four as the most plausible.

3.3.2 Downside risk

An alternative to the mean-variance approach of measuring or identifying risk is using an asymmetric measure of risk. The downside risk approach may more accurately address producers' concerns because it identifies returns below a specified target or benchmark return level which is often a more troublesome issue than the traditional variance or standard deviation measure (Harlow 1991). Previous studies have discovered an aversion to downside risk or an avoidance of "situations which offer the potential for substantial gains but which also leave them even slightly vulnerable to losses below some critical level" (Menezes, Geiss and Tressler 1980, 921).

Downside risk measures are asymmetric measures of risk because they focus on the left tail of the return distribution below a specified level instead of the entire return distribution. A necessary condition for downside risk aversion is a positive third derivative of the utility function (Menezes, Geiss and Tressler 1980). Therefore, it is possible for both risk averse and risk plunging individuals to be downside risk averse. This concept has been addressed in other contexts without the formal definition of downside risk where pricing strategies and demand for products is concerned (Nichol 1941, Lanzillotti 1958).

Mao (1970) interviewed executives from medium and large companies and found that most researchers use mean-variance for measuring risk; however, the executives were more concerned with a semi-variance measure instead. The executives in Mao's study were specifically asked about investment risk and their responses indicated they were concerned about meeting a target rate of return and downside deviations from that return.

Tauer (1983) suggests farmers may be concerned about selling under their cost of production or a negative cash flow in a given year. Tauer provides an example with a critical target return of $1,000. The corresponding downside risk measure was the weighted sum of the deviations below the target return level over a five-year period (Tauer 1983).

Watts, Held, and Helmers (1984) set a target income equal to the mean income established from a minimization of total absolute deviation (MOTAD) problem. The risk measure used in the analysis was the total negative deviations from the target income level over a six-year period (Watts, Held and Helmers 1984). As the authors note, when distributions are skewed, the Target MOTAD solutions will differ from the MOTAD solutions.

3.4 Efficiency and Risk

One response to risk is to utilize risk-reducing inputs such as irrigation systems, insurance, and pesticides (Just and Pope 1978, Robinson and Barry 1987). Many inputs are viewed as risk-increasing because they increase the expected output and variance of output including land and fertilizer. Risk-reducing inputs need to be considered carefully in modeling and decision making as they have different effects on expected returns, variances, and costs.

A number of methods and tools can be used to reduce the risk experienced by farm firms. These methods include, but are not limited to, hedging, diversification, share leasing, obtaining more information, government programs, and new technology (Robinson and Barry 1987). The only method mentioned here because of its direct connection with efficiency analysis will be new production technology. Production technology is the process used to convert inputs into outputs. Adoption of new technology while risky, especially if the process is unfamiliar, may increase the firm's expected output and/or result in a more efficient use of inputs (Robinson and Barry 1987).

Risk must be included into efficiency analysis in order to more accurately account for the differences in efficiency scores among firms. A risk averse producer will produce less than a risk neutral or risk plunging producer and decrease production levels as perceived risk increases (Robinson and Barry 1987, Ben Jemaa 2007). Without accounting for risk in the efficiency estimation, firms will be deemed more inefficient.

As shown in Chapter 2, frontiers have been estimated a number of ways primarily either using stochastic frontier analysis involving econometric methods or using the mathematical programming approach of nonparametric methods. The nonparametric approach of data envelopment analysis (DEA) has several desirable properties and will be used in this study. A frontier is constructed based on data for the firms in the sample. DEA compares the firms in terms of their use of inputs and resulting level of output to construct a benchmark or best practice frontier (Coelli, et al. 2005).

Coelli, et al. (2005) discuss ways to adjust for factors that may influence the efficiency of the firm when the factors are not traditional inputs or outputs (e.g., risk). One method is to consider the case of a non-discretionary DEA. If the variable is assumed to have a positive effect on efficiency, it should be included as a non-discretionary input (Coelli, et al. 2005). A non-discretionary input is included in the same manner as the discretionary inputs in the analysis. However, a firm has little control over a non-discretionary variable and the level is fixed. Alternatively, if the variable is assumed to have a negative effect, it should be included as a non-discretionary output. Risk could fall into either category: positive or negative effect. It is expected that including risk into the calculation will increase the efficiency score, so while risk itself has a negative effect, its inclusion into the efficiency calculation would be positive. Therefore, risk should be included as an input. This is consistent with the design of a "bad" output (Chang 1999, Färe and Grosskopf 2005).

It is necessary to mention that despite the benefits and desirable properties associated with DEA, it is not without issues and limitations. These include: outliers influencing the results, measurement error or noise can affect the shape of the frontier, efficiency scores are only relative to the best firms in the sample, mean efficiency scores are not comparable across samples, and not accounting for environmental differences (e.g., risk) may give misleading results (Coelli, et al. 2005). This study will alleviate one of the issues associated with traditional DEA models by accounting for the risk experienced by the sample farms.

Chapter 4 - Methods

This chapter provides an explanation of the methods used to calculate the respective efficiency measures and the risk measures. There are three subsections: efficiency measures, risk, and risk preference. The efficiency measures subsection is further divided into cost and revenue efficiency. The risk subsection is divided into the two primary measures of risk used in this analysis: variability in outputs and downside risk. The risk preference subsection provides a description of the method used to calculate each producer's risk preference score from Pope's (2009) survey.

4.1 Efficiency Measures

The methods used to estimate cost and revenue efficiency scores in this study are presented below. Both cost and revenue based efficiency are further divided into overall, pure technical, allocative, scale, and economic (cost or revenue) efficiency scores. The nonparametric approach known as data envelopment analysis (DEA) was used to estimate the efficiency scores. These models are essentially a "black box" where inputs are transformed into outputs without specifying a lot of structure or a functional form (Färe and Grosskopf 1996). The efficiency measures used developed from a desire to measure firm efficiency with multiple inputs considered. The original measures developed are now referred to as technical efficiency, allocative efficiency, and their product, economic efficiency (Farrell 1957).

Annual observations for each farm were used to estimate efficiency relative to all the other farms in the data set in a particular year. In order to estimate the DEA, data is needed on inputs, outputs, and prices. The data are described in the following chapter. Only focusing on the inputs and outputs necessary in production attributes all differences from the optimal as inefficiency. This overstates firm inefficiency and overstates the potential improvements that can be made. The inclusion of risk as mentioned previously and described in more detail below will provide a better indication of the true inefficiency and potential for improvement. Additionally, risk averse producers operate with different cost and revenue functions than those with other preferences. With this in mind, risk preferences will be introduced to the efficiency analysis to identify if those individuals are also relatively less efficient.

4.1.1 Input-oriented (Cost) Efficiency

Cost or input-based efficiency measures are often used when analyzing production agriculture because of the information available on input prices and a belief that producers are cost minimizers.

Farms with an overall efficiency of 1 are producing on the production possibility frontier, are using the optimal mix of inputs and are producing at the most efficient scale for their level of production. Overall efficiency (COE) for the *i*-th firm is measured using the following equation:

(1) COE = $c_i' x_i^{*CRS} / c_i' x_i$,

where c is a vector of input prices, x is a vector of input levels used, i signifies the firm of interest, $*$ indicates the optimal value, and the superscript CRS specifies the optimal value was solved for under constant returns to scale technology (Färe, Grosskopf and Lovell 1985, Coelli, et al. 2005).

The denominator in equation (1) is the actual cost for the individual firm. The numerator is determined using the following linear program:

(2) $\text{Min}_{\text{x}^{*\text{CRS}}} \; c_i' x_i^{*CRS}$

subject to:

$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}^{*CRS}$

$$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}^{*CRS}$$

$$\ldots$$

$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}^{*CRS}$$

$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} \geq 0$$

$$\ldots$$

$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} \geq 0,$$

where the notation is as previously defined and y is a vector of outputs, $z_k \in \Re^{+}$ and measures the intensity of use of the *k*-th firm's technology, the subscript *k* denotes the number of firms, the subscript *n* is the number of inputs, and the subscript *m* is the number of outputs (Färe, Grosskopf and Lovell 1985, Coelli, et al. 2005).

Pure technical efficiency measured using an input-based orientation (CTE) measures the proportional decrease in inputs required to reach the same level of output. Technical efficiency measures whether a farm is producing on the production possibility frontier. A farm that produces on the production possibility frontier is minimizing input given their current output levels. A farm that is not producing on the production frontier is not maximizing output given their current input levels and is thus technically inefficient. CTE is calculated using the following linear programming problem:

(3) CTE = Min λ_i

subject to:

$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq \lambda x_{1i}$$

$$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq \lambda x_{2i}$$

$$\ldots$$

$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq \lambda x_{ni}$$

$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} \geq 0$

...

$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} \geq 0$

$z_1 + z_2 + \cdots + z_k = 1,$

where the last line in model (3) is a restriction that the intensity vector sums to one and allows variable returns to scale in the technology (Färe, Grosskopf and Lovell 1985, Coelli, et al. 2005).

Allocative efficiency (CAE) can be determined by dividing the minimum cost under variable returns to scale by the actual cost multiplied by technical efficiency. Allocative efficiency measures whether a farm is using the optimal mix of inputs. A farm that is allocatively efficient is producing on the average cost frontier or is minimizing cost given their current level of inputs and outputs.

(4) CAE = $c_i{}'x_i^* / c_i{}'\lambda_i x_i$.

The numerator of equation (4) can be determined using the following linear programming problem for each firm:

(5) $\text{Min}_{x^*}\ c_i{}'x_i^*$

subject to:

$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}^*$

$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}^*$

...

$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}^*$

$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} \geq 0$

...

$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} \geq 0$

$z_1 + z_2 + \cdots + z_k = 1.$

Economic or cost efficiency (CE) is a short-run efficiency measure similar to the COE except the firms are allowed to operate under variable returns to scale. Farms with an economic efficiency of 1 are producing on the production possibility frontier and are using the optimal input mix.

(6) CE = $c_i{}'x_i^* / \, c_i{}'x_i$,

where the numerator in equation (6) is solved for using model (5) and the denominator is the actual cost for the *i*-th firm (Färe, Grosskopf and Lovell 1985).

Scale efficiency (CSE) can be determined by dividing the minimum cost from model (2) by the minimum cost from model (5) (Färe, Grosskopf and Lovell 1985). A farm that is scale efficient is producing at the lowest per unit cost and is at the most efficient size.

(7) CSE = $c_i{}'x_i^{*CRS} / c_i{}'x_i^*.$

A connection among the measures above allows several of them to be rewritten as products of the others. COE is the product of CTE, CAE, and CSE. CE is the product of CTE and CAE.

The efficiency measures for each firm will range from 0 to 1. A value of 1 represents efficiency. A firm may be efficient in some measures and inefficient in others. The values will vary based off of the firms included in the analysis. The efficiency scores can be ranked and analyzed; however, there is not a direct comparison between efficiency scores from one study and efficiency scores from another study.

4.1.2 Output-oriented (Revenue) Efficiency

The revenue or output-based efficiency measures are less commonly observed than the cost efficiency scores. This may be because of data limitations or the fact that in production agriculture producers may have less control over the quantity of outputs actually produced than the inputs used in production (Coelli, et al. 2005). The revenue efficiency measures are very similar in construction and interpretation to the cost efficiency measures.

Overall efficiency (ROE) for the *i*-th firm is measured using the following equation:

(8) ROE = $p_i' y_i / p_i' y_i^{*CRS}$,

where the variables are as defined previously and p is a vector of output prices (Färe, Grosskopf and Lovell 1985, Coelli, et al. 2005). Farms with an overall efficiency of 1 are producing on the production possibility frontier, are producing the optimal mix of outputs and are producing at the most efficient scale for their level of production. The most notable difference between the cost and revenue efficiency measures is the fact the values used in their estimation are inverted. This is necessary to constrict the revenue efficiency measures to range from 0 to 1.

The numerator in equation (8) is the actual revenue of the individual firm. The denominator is determined using the following linear program:

(9) $\mathrm{Max}_{y^{*CRS}}\ p_i' y_i^{*CRS}$

subject to:

$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}$$

$$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}$$

...

$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}$$

$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i}^{*CRS} \geq 0$$

...

$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi}^{*CRS} \geq 0,$$

where the notation is as previously defined (Cooper, Seiford and Tone 2007).

Pure technical efficiency measured using an output-based orientation (RTE) measures the proportional increase in outputs that could be produced using the same amount of inputs. Technical efficiency measures whether a farm is producing on the production possibility frontier. A farm that produces on the production possibility frontier is maximizing output given their current input levels. A farm that is not producing on the production frontier is not maximizing output given their current input levels and is thus technically inefficient.

(10) RTE = $1/\phi_i$.

Following Coelli, et al. (2005), the denominator for RTE is calculated using the following linear programming problem:

(11) Max ϕ_i

subject to:

$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}$

$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}$

...

$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}$

$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - \phi y_{1i} \geq 0$

...

$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - \phi y_{mi} \geq 0$

$z_1 + z_2 + \cdots + z_k = 1.$

Allocative efficiency (RAE) can be determined by dividing the actual revenue of the firm by the technical efficiency and maximum revenue under variable returns to scale. Allocative efficiency measures whether a farm is producing the optimal mix of outputs. A farm that is allocatively efficient is maximizing revenue given their current level of inputs and outputs.

(12) RAE = $p_i'\phi_i y_i / p_i' y_i^*$.

The denominator of equation (12) can be determined using the following linear programming problem for each firm:

(13) $\text{Max}_{y^*}\ p_i' y_i^*$

subject to:

$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}$$

$$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}$$

$$\ldots$$

$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}$$

$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i}^* \geq 0$$

$$\ldots$$

$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi}^* \geq 0$$

$$z_1 + z_2 + \cdots + z_k = 1.$$

Economic or revenue efficiency (RE) is a short-run efficiency measure similar to the ROE except the firms are allowed to operate under variable returns to scale. Farms with an economic efficiency of 1 are producing on the production possibility frontier and are producing the optimal output mix.

(14) RE = $p_i' y_i / \, p_i' y_i^*$,

where the denominator in equation (14) is solved for using model (13) and the numerator is the actual cost for the *i*-th firm (Färe, Grosskopf and Lovell 1985).

Scale efficiency (RSE) can be determined by dividing the maximum revenue from model (13) by the maximum revenue from model (9) (Färe, Grosskopf and Lovell 1985). A scale efficient farm is operating at the optimal size.

(15) RSE = $p_i' y_i^* / p_i' y_i^{*CRS}$.

A connection among the measures above allows several of them to be rewritten as products of the others. ROE is the product of RTE, RAE, and RSE. RE is the product of RTE and RAE.

4.2 Risk

Two risk measures were calculated and included in the efficiency measures to estimate risk adjusted efficiency scores. A description of each measure and its incorporation into efficiency is discussed below.

4.2.1 Variability in Outputs

The first risk measure included in this efficiency analysis is variability in outputs measured as the standard deviation of outputs in the previous 10-year period. The efficiency scores are estimated for each firm in each year, so this allows the risk measure to also fluctuate each year as it is updated with the information from the prior 10 years.

Standard deviation represents how much variation there is from the average output levels (Robinson and Barry 1987). A low standard deviation indicates the values are all close to the average and in this context, low risk. A larger standard deviation indicates the values are spread out from the average, and are thus indicators of higher risk. Standard deviation, square root of variance, is preferred to variance because unlike variance, it is expressed in the same units as the original data (Robinson and Barry 1987).

The risk measures are included as non-discretionary inputs in the efficiency calculation. This is equivalent to its inclusion as a “bad output”. A non-discretionary input is an input that the manager has little to no control over. Therefore, the model is only structured to seek a reduction in the inputs over which the manger does have control (Coelli, et al. 2005). The example below illustrates how the minimum cost under variable returns to scale is modified with the inclusion of additional constraints to include the risk variables. Two outputs are included in this analysis (crop and livestock), so there are two corresponding risk measures.

(16) $\text{Min}_{x^*} \; c_i{}' x_i^*$

subject to:

$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}^*$$

$$x_{21}z_1 + x_{22}z_2 + \cdots + x_{2k}z_k \leq x_{2i}^*$$

$$\ldots$$

$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}^*$$

$$r_{11}z_1 + r_{12}z_2 + \cdots + r_{1k}z_k \leq r_{1i}$$

$$r_{21}z_1 + r_{22}z_2 + \cdots + r_{2k}z_k \leq r_{2i}$$

$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} \geq 0$$

$$\ldots$$

$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} \geq 0$$

$$z_1 + z_2 + \cdots + z_k = 1,$$

where r represents the risk measure. Note that risk is included as an input constraint, but it is not a choice variable in the optimization. In other words, the level of the non-discretionary variable is not allowed to change.

4.2.2 Downside Risk

The second measure of risk chosen was a weighted summation of the negative difference between net farm income and unpaid labor during the 10 year period prior to the year of interest in the analysis. A negative difference between net farm income and unpaid labor would indicate a negative return to equity. A negative net farm income would be an indicator of stress to the farm. A positive difference between net farm income and unpaid labor was assigned a value of zero and all 10 years were weighted equally. This measure is similar to that used by Tauer (1983) who estimated downside risk as the weighted sum of the deviations below a target return level.

This measure was included in the efficiency analysis as a non-discretionary input. This is illustrated in model (18) above. In this case, there is one additional risk constraint instead of two.

4.3 Risk Preference

Risk preference scores were obtained from a survey conducted by Pope (2009). The survey was sent to Kansas Farm Management Association members with a whole-farm analysis and cowherd in 2008. Five questions in the survey were related to risk: how a respondent's neighbor would describe their risk taking behavior, retained ownership strategies, best and worst case calf return strategies, and questions related to investing in an innovative business with the chance for a large gain, but a significant chance of loss. Possible question responses were ordered from risk averse to risk plunging. There were 272 respondents to the questions and risk preference was based on the responses given. The scores were determined by assigning a "1" to "a", "2" to "b", etc. and squaring the scores for each question. The scores could range from 5 for an extremely risk averse individual up to 113 for a risk plunging individual. The scores in this sample ranged from 5 to 86 (Frasier-Pope, Schroeder and Langemeier 2010). The inverse of the risk preference scores is included as an input in the efficiency estimation for the respective farms. The use of the inverse of the risk preference score is necessary to remain consistent with traditional inputs in efficiency analysis where less input is better. Lower risk aversion is expected to be better.

The next chapter provides a summary of the data used for the extended risk and efficiency analyses as well as the data with the corresponding risk preference score. The data is used to estimate efficiency scores for each farm in each year using the methods described above. Initial efficiency scores are estimated without the risk or risk preference variables included. Corresponding efficiency scores are estimated with the inclusion of variability in outputs, downside risk, and the inverse risk preference score separately. Comparisons among the efficiency scores are made to examine the differences among the farms and the portion of inefficiency explained through the risk or risk preference measures.

Chapter 5 - Data

Two separate data sets were used in the analysis. The farms chosen for this study were members of the Kansas Farm Management Association (KFMA n.d.). For more information on the variables available in the KFMA databank and variable definitions, see Langemeier (2010). The 256 farms included in the first analysis all had continuous data from 1993 to 2010. The 258 farms in the second analysis had whole-farm data available for 2008 and completed the portion of a survey by Pope (2009) related to risk preferences sent to all KFMA farms with a whole-farm analysis and cowherd in 2008. Both data sets are described in more detail below.

5.1 Whole-farm Analysis Data for 1993-2010

In order to compute efficiency indices, information was required on inputs, input prices, outputs, and output prices. Five inputs were used in the analysis: labor, crop input, fuel, livestock input, and capital. All costs were annualized. Labor was represented by the number of workers (paid and unpaid) on the farm. Labor price was obtained by dividing labor cost by the number of workers. Implicit input quantities for the crop input, fuel, the livestock input, and capital were computed by dividing the respective input costs by USDA input price indices (USDA). Crop inputs consisted of seed; fertilizer; herbicide and insecticide; crop marketing and storage; and crop insurance (Langemeier 2010). Fuel was comprised of fuel, auto expense, irrigation energy, and utilities. Livestock inputs included dairy expense; purchased feed; veterinarian expense; and livestock marketing and breeding. The capital input included repairs; machine hire; general farm insurance; property taxes; organization fees, publications, and travel; conservation; interest; cash farm rent; and interest charge on net worth (Langemeier 2010).

Outputs consisted of crops and livestock. Implicit crop and livestock quantities were computed by dividing crop income and livestock income by Kansas crop price and livestock price indices (USDA). Summary statistics for the sample of farms are presented in Table 5.1.

Table 5.1: Summary Statistics for Sample of Kansas Farms, 1993-2010

	Mean	Standard Deviation
Inputs		
Labor	1.38	0.80
Crop	109,276	103,616
Fuel	36,111	31,276
Livestock	14,646	35,424
Capital	183,022	130,395
Outputs		
Crop	333,730	310,042
Livestock	41,465	64,830
Farm Characteristics		
Gross Farm Income	277,475	264,567
Value of Farm Production	269,909	258,557
Net Farm Income	67,144	98,045
Feed Grain Income	77,501	124,674
Hay and Forage Income	8,802	37,734
Oilseed Income	62,913	108,923
Small Grains Income	49,151	65,108
Beef Income	32,625	55,306
Dairy Income	144	1,832
Swine Income	732	7,289
Total Acres	1,821	1,234
Crop Labor Percentage	86.06%	15.45%
Diversification Index	0.2515	0.1537
Financial Efficiency Ratios		
Profit Margin	0.1452	0.4583
Asset Turnover	0.2963	0.2106
Rate of Return on Investment	0.0430	0.0936

The average value of farm production over the 18-year period was $269,909. Net farm income was $67,144. Average total acres were 1,821. On average, approximately 86 percent of farmers' time was spent on crop production. The largest source of crop income was feed grains (corn and grain sorghum). Beef income was by far the largest source of livestock income. The average profit margin and asset turnover ratios were 0.1452 and 0.2963, respectively.

The diversification index was computed using a standard Herfindahl index by summing the squared share of income from each enterprise. A value of 1 would indicate that all income was coming from one source. Alternatively, a smaller value would indicate that the farm was more diversified and income was coming from several enterprises.

The first set of risk measures used include the standard deviation of both crop output and livestock output. The second risk measure is the equally weighted summation of net farm income below the amount needed to pay for unpaid labor. If net farm income was greater than the amount needed to pay for unpaid labor, downside risk was zero. If net farm income was less than the amount needed to pay for unpaid labor the absolute value of net farm income minus unpaid labor was used. The risk measures were based on the prior 10-year period. This reduced the number of years in the efficiency analysis from 18 to 8. The risk measures for year 2003 were based on the data from 1993-2002, the risk measures for 2004 were based on the information from 1994-2003, etc. The number of farms with a downside risk of zero ranged from 8 in 2003 up to 17 in 2009. A total of 25 individual farms had a downside risk of zero for at least one previous 10-year period, and 3 farms had a downside risk of zero every year. Summary statistics including inputs, outputs, risk measures, and select farm characteristics and financial ratios for the eight years in the efficiency analysis are illustrated in the tables below.

Table 5.2 presents the summary statistics for 2003. The first set of risk measures, variability in crop outputs and variability in livestock outputs, were 89,938 and 15,814, respectively. The second risk measure examined, downside risk, was 13,880. This indicates on average net farm income was not able to cover unpaid labor. The risk measures represent the risk from the previous 10-year period, 1993-2002. The average value of farm production was $247,722 and the average net farm income was $58,840. The profit margin and asset turnover ratios were 0.1269 and 0.2959, respectively.

Table 5.3 presents the summary statistics for 2004. The average risk measures for variability in crop outputs, variability in livestock outputs, and downside risk were 89,184, 15,716, and 14,243, respectively. The average value of farm production was $265,720 and net farm income was $67,301. The average profit margin and asset turnover ratios were 0.1345 and 0.2962, respectively.

Table 5.4 represents the summary statistics for 2005. The average value of farm production and net farm income were $281,477 and $54,534, respectively. The average profit margin and asset turnover ratios were 0.0714 and 0.2727, respectively.

Table 5.5 provides summary statistics for 2006. The average value of farm production and net farm income were $294,822 and $56,218, respectively. The average profit margin and asset turnover ratios were 0.0804 and 0.2654, respectively.

Table 5.6 provides summary statistics for 2007. The average value of farm production was $382,708 and net farm income was $110,811. The average profit margin and asset turnover ratios were 0.2008 and 0.3078, respectively.

Table 5.7 provides summary statistics for 2008. The average value of farm production was $471,679 and net farm income was $151,042. The average profit margin and asset turnover ratios were 0.2378 and 0.3378, respectively.

Table 5.2: Summary Statistics for Sample of Kansas Farms, 2003

	Mean	Standard Deviation
Inputs		
Labor	1.35	0.76
Crop	114,655	105,679
Fuel	36,966	36,446
Livestock	16,431	35,435
Capital	196,574	138,706
Outputs		
Crop	342,760	295,767
Livestock	43,631	68,515
Risk Measures		
Variability in Crop	89,938	82,638
Variability in Livestock	15,814	17,095
Downside Risk	13,880	9,550
Farm Characteristics		
Value of Farm Production	247,722	195,076
Net Farm Income	58,840	67,531
Feed Grain Income	57,217	94,978
Hay and Forage Income	5,901	15,645
Oilseed Income	48,040	75,018
Small Grains Income	62,726	68,186
Beef Income	37,326	61,395
Dairy Income	275	3,689
Swine Income	209	3,327
Total Acres	1,883	1,282
Crop Labor Percentage	86.65%	15.56%
Diversification Index	0.2442	0.1530
Financial Efficiency Ratios		
Profit Margin	0.1269	0.2764
Asset Turnover	0.2959	0.1985
Rate of Return on Investment	0.0376	0.0839

Table 5.3: Summary Statistics for Sample of Kansas Farms, 2004

	Mean	Standard Deviation
Inputs		
Labor	1.36	0.76
Crop	116,804	103,244
Fuel	34,088	29,399
Livestock	18,305	61,283
Capital	199,162	138,323
Outputs		
Crop	327,266	278,008
Livestock	54,335	89,224
Risk Measures		
Variability in Crop	89,184	81,608
Variability in Livestock	15,716	18,491
Downside Risk	14,243	9,871
Farm Characteristics		
Value of Farm Production	265,720	206,570
Net Farm Income	67,301	70,391
Feed Grain Income	73,378	98,036
Hay and Forage Income	9,758	45,921
Oilseed Income	54,432	70,134
Small Grains Income	46,548	49,950
Beef Income	47,175	78,649
Dairy Income	86	883
Swine Income	440	5,609
Total Acres	1,885	1,330
Crop Labor Percentage	86.49%	15.76%
Diversification Index	0.2388	0.1512
Financial Efficiency Ratios		
Profit Margin	0.1345	0.3014
Asset Turnover	0.2962	0.1932
Rate of Return on Investment	0.0398	0.0858

Table 5.4: Summary Statistics for Sample of Kansas Farms, 2005

	Mean	Standard Deviation
Inputs		
Labor	1.34	0.76
Crop	129,871	117,400
Fuel	34,015	30,171
Livestock	17,252	54,017
Capital	196,865	134,684
Outputs		
Crop	420,560	403,106
Livestock	50,988	86,615
Risk Measures		
Variability in Crop	86,998	77,222
Variability in Livestock	16,607	22,882
Downside Risk	14,199	9,815
Farm Characteristics		
Value of Farm Production	281,477	239,559
Net Farm Income	54,534	79,316
Feed Grain Income	70,029	135,566
Hay and Forage Income	8,692	52,927
Oilseed Income	60,616	74,390
Small Grains Income	44,502	56,448
Beef Income	47,610	81,543
Dairy Income	44	682
Swine Income	116	1,714
Total Acres	1,904	1,364
Crop Labor Percentage	87.15%	15.51%
Diversification Index	0.2405	0.1430
Financial Efficiency Ratios		
Profit Margin	0.0714	0.2709
Asset Turnover	0.2727	0.1773
Rate of Return on Investment	0.0195	0.0750

Table 5.5: Summary Statistics for Sample of Kansas Farms, 2006

	Mean	Standard Deviation
Inputs		
Labor	1.33	0.75
Crop	126,478	121,610
Fuel	34,122	28,947
Livestock	16,570	43,852
Capital	183,127	123,369
Outputs		
Crop	391,142	350,649
Livestock	40,085	60,087
Risk Measures		
Variability in Crop	88,019	82,492
Variability in Livestock	16,606	25,623
Downside Risk	14,413	10,134
Farm Characteristics		
Value of Farm Production	294,822	239,203
Net Farm Income	56,218	79,805
Feed Grain Income	88,741	127,249
Hay and Forage Income	13,773	39,382
Oilseed Income	55,285	69,932
Small Grains Income	60,654	67,129
Beef Income	36,362	55,316
Dairy Income	97	1,487
Swine Income	163	2,398
Total Acres	1,949	1,495
Crop Labor Percentage	86.74%	15.73%
Diversification Index	0.2478	0.1469
Financial Efficiency Ratios		
Profit Margin	0.0804	0.3957
Asset Turnover	0.2654	0.1776
Rate of Return on Investment	0.0213	0.0823

Table 5.6: Summary Statistics for Sample of Kansas Farms, 2007

	Mean	Standard Deviation
Inputs		
Labor	1.32	0.80
Crop	140,435	140,685
Fuel	31,947	29,038
Livestock	15,332	41,862
Capital	191,231	132,825
Outputs		
Crop	378,228	351,074
Livestock	39,494	65,737
Risk Measures		
Variability in Crop	84,161	79,789
Variability in Livestock	16,312	25,510
Downside Risk	16,087	11,002
Farm Characteristics		
Value of Farm Production	382,708	330,348
Net Farm Income	110,811	118,651
Feed Grain Income	135,623	179,967
Hay and Forage Income	12,260	44,812
Oilseed Income	85,376	122,691
Small Grains Income	45,475	64,019
Beef Income	38,725	65,061
Dairy Income	72	1,145
Swine Income	91	1,190
Total Acres	1,926	1,303
Crop Labor Percentage	86.54%	16.01%
Diversification Index	0.2914	0.1542
Financial Efficiency Ratios		
Profit Margin	0.2008	0.3267
Asset Turnover	0.3078	0.2166
Rate of Return on Investment	0.0618	0.0955

Table 5.7: Summary Statistics for Sample of Kansas Farms, 2008

	Mean	Standard Deviation
Inputs		
Labor	1.32	0.81
Crop	122,124	109,077
Fuel	31,576	26,767
Livestock	11,949	29,743
Capital	205,289	140,888
Outputs		
Crop	340,695	310,778
Livestock	33,390	54,166
Risk Measures		
Variability in Crop	83,870	78,695
Variability in Livestock	15,522	25,168
Downside Risk	16,671	11,439
Farm Characteristics		
Value of Farm Production	471,679	405,478
Net Farm Income	151,042	167,445
Feed Grain Income	146,692	192,319
Hay and Forage Income	16,899	61,689
Oilseed Income	116,532	160,015
Small Grains Income	108,802	122,278
Beef Income	31,856	52,033
Dairy Income	80	899
Swine Income	78	1,001
Total Acres	1,970	1,352
Crop Labor Percentage	87.18%	15.09%
Diversification Index	0.2722	0.1532
Financial Efficiency Ratios		
Profit Margin	0.2378	0.8030
Asset Turnover	0.3378	0.2547
Rate of Return on Investment	0.0803	0.1040

Table 5.8 illustrates the summary statistics for 2009. The average value of farm production and net farm income were $436,292 and $119,859, respectively. The average profit

margin and asset turnover ratios were 0.1817 and 0.2857, respectively.

Table 5.8: Summary Statistics for Sample of Kansas Farms, 2009

	Mean	Standard Deviation
Inputs		
Labor	1.32	0.82
Crop	139,737	127,747
Fuel	32,315	27,776
Livestock	12,756	37,967
Capital	232,059	161,523
Outputs		
Crop	427,099	380,459
Livestock	36,396	65,498
Risk Measures		
Variability in Crop	81,787	76,784
Variability in Livestock	15,914	25,173
Downside Risk	15,235	11,536
Farm Characteristics		
Value of Farm Production	436,292	373,566
Net Farm Income	119,859	139,849
Feed Grain Income	127,903	154,704
Hay and Forage Income	10,363	43,444
Oilseed Income	155,197	224,006
Small Grains Income	70,755	92,469
Beef Income	31,331	56,708
Dairy Income	0	0
Swine Income	4	63
Total Acres	1,966	1,356
Crop Labor Percentage	87.81%	14.75%
Diversification Index	0.2975	0.1683
Financial Efficiency Ratios		
Profit Margin	0.1817	0.6747
Asset Turnover	0.2857	0.1892
Rate of Return on Investment	0.0519	0.0883

Table 5.9 provides summary statistics for 2010. The average value of farm production

was $476,051 and net farm income was $139,897. The average profit margin and asset turnover ratios were 0.1972 and 0.2732, respectively.

Table 5.9: Summary Statistics for Sample of Kansas Farms, 2010

	Mean	Standard Deviation
Inputs		
Labor	1.31	0.85
Crop	145,314	134,689
Fuel	32,857	31,106
Livestock	13,216	51,261
Capital	262,114	189,408
Outputs		
Crop	443,253	408,445
Livestock	43,338	92,267
Risk Measures		
Variability in Crop	82,287	77,935
Variability in Livestock	15,600	24,885
Downside Risk	14,818	12,178
Farm Characteristics		
Value of Farm Production	476,051	414,220
Net Farm Income	139,897	165,266
Feed Grain Income	170,914	228,050
Hay and Forage Income	14,938	73,427
Oilseed Income	146,708	169,328
Small Grains Income	64,261	96,635
Beef Income	43,495	94,892
Dairy Income	47	658
Swine Income	12	186
Total Acres	1,977	1,343
Crop Labor Percentage	87.87%	14.80%
Diversification Index	0.2938	0.1589
Financial Efficiency Ratios		
Profit Margin	0.1972	0.8613
Asset Turnover	0.2732	0.1890
Rate of Return on Investment	0.0539	0.0817

5.2 Whole-farm Analysis Data in 2008 with Risk Preference Score

Five inputs were used in the analysis: labor, crop input, fuel, livestock input, and capital. All costs were annualized. Labor was represented by the number of workers (paid and unpaid) on the farm. Labor price was obtained by dividing labor cost by the number of workers. Implicit input quantities for the crop input, fuel, the livestock input, and capital were computed by dividing the respective input costs by USDA input price indices (USDA). Crop inputs consisted of seed; fertilizer; herbicide and insecticide; crop marketing and storage; and crop insurance (Langemeier 2010). Fuel was comprised of fuel, auto expense, irrigation energy, and utilities. Livestock inputs included dairy expense; purchased feed; veterinarian expense; and livestock marketing and breeding. The capital input included repairs; machine hire; general farm insurance; property taxes; organization fees, publications, and travel; conservation; interest; cash farm rent; and interest charge on net worth (Langemeier 2010).

Outputs consisted of crops and livestock. Implicit crop and livestock quantities were computed by dividing crop income and livestock income by Kansas crop price and livestock price indices (USDA).

The risk preference score was created by Pope (2009) from a survey she sent to KFMA members. For more information about the survey and responses, please see Pope (2009). Five questions in the survey were related to risk: how a respondent's neighbor would describe their risk taking behavior, retained ownership strategies, best and worst case calf return strategies, and questions related to investing in an innovative business with the chance for a large gain, but a significant chance of loss. A smaller risk preference score indicates more risk aversion and the scores could range from 5 to 113. The 258 observations used in this analysis ranged from 5 to 86. Pope (2009) breaks the scores down as follows: 5 to 21, strongly risk averse; 22 to 38, slightly risk averse; 39 to 86, all other risk preference levels. There were 94 farms categorized as strongly risk averse, 131 slightly risk averse, and 33 farms in the other risk preferences category. Summary statistics are presented in Table 5.10.

Table 5.10: Summary Statistics for Sample of Kansas Farms with Risk Preference Scores

	Mean	Standard Deviation
Inputs		
Labor	1.31	0.71
Crop	98,572	90,937
Fuel	29,336	25,283
Livestock	30,971	63,295
Capital	193,025	145,210
Outputs		
Crop	279,969	289,922
Livestock	77,881	100,482
Risk Measure		
Risk Preference Score	25.82	11.57
Farm Characteristics		
Value of Farm Production	420,572	392,307
Net Farm Income	113,480	171,106
Feed Grain Income	111,751	165,288
Hay and Forage Income	17,294	51,663
Oilseed Income	84,000	127,642
Small Grains Income	95,806	121,993
Beef Income	74,816	105,167
Dairy Income	1,229	16,394
Swine Income	435	4,447
Total Acres	2,208	1,654
Crop Labor Percentage	70.14%	20.04%
Diversification Index	0.4307	0.1631
Financial Efficiency Ratios		
Profit Margin	0.1883	0.4996
Asset Turnover	0.3291	0.2525
Rate of Return on Investment	0.0620	0.1239

The average value of farm production for this sample of farms in 2008 was $420,572. Net farm income was $113,480. Average total acres were 2,208. On average, approximately 70 percent of farmers' time was spent on crop production. The largest source of crop income was feed grains (corn and grain sorghum). Beef income was by far the largest source of livestock income. The average profit margin and asset turnover ratios were 0.1883 and 0.3291, respectively. The average risk preference score for the 258 farms was 25.82. This falls in the slightly risk averse category.

There are some distinct differences in characteristics between the farms in Table 5.7 and Table 5.10. Compared to the characteristics of farms in 2008 included in the 1993-2010 data set, the farms in 2008 with a risk preference score had fewer crop and more livestock inputs and outputs and less income coming from crop enterprises and more from beef. The farms with a risk preference score devoted approximately 30 percent of their labor towards livestock production compared to less than 13 percent of time devoted to livestock production for the farms in the longer analysis. This is not surprising considering a requirement to receive the survey was a beef-cow herd (Pope 2009).

Chapter 6 - Results

The results are divided into three sections. The first section focuses on the efficiency measures for the panel data set. The second section focuses specifically on the cost- and revenue-based economic efficiency. The third section focuses on the efficiency measures for the cross-sectional data set with risk preference scores.

6.1 Results for Whole-farm Analysis, 2003-2010

Efficiency scores were calculated for the 256 farms in the sample for each year from 2003-2010. The efficiency scores were first estimated using only the five inputs (labor, crop, fuel, livestock, and capital) and two outputs (crop and livestock). Efficiency scores were then recalculated including variability in outputs and downside risk as risk measures.

Results for the ten measures both without and with the two risk alternatives are presented below. Table 6.1 and Table 6.2 present the results for average cost and revenue efficiencies per year. The cost and revenue efficiencies also known as economic efficiency measures are an overall type efficiency measure calculated under variable returns to scale. They are arguably the most informative of the efficiency measures and will be discussed in more detail than the other eight efficiency measures.

On average between 8 and 13 farms were cost efficient each year (Table 6.1). The difference from the least efficient to the most efficient farm was 0.7496. In terms of average costs, the consequences from being the least efficient compared to the most efficient farm was $232,643. This is a large impact considering the average net farm income was $67,144. The inclusion of risk measured as variability in outputs increased the number of efficient farms to between 25 and 39 each year while the use of downside risk as a measure of risk increased the number of efficient farms to 17 to 29 per year. The farms were 63.25 to 71.93 percent efficient before accounting for risk. The inclusion of variability or downside risk, increased the average efficiency scores to range from 67.70 to 76.23 percent and 64.47 to 74.37 percent, respectively. The portion of inefficiency explained by the risk measures was calculated by dividing the change in inefficiency between the risk adjusted and traditional efficiency measures divided by the inefficiency of the farms without the risk measures. Risk as measured by variability in outputs explains between 9.02 and 21.01 percent of the cost inefficiency each year for all farms and between 24.27 and 31.73 percent of cost inefficiency for the farms impacted by the inclusion of risk. Downside risk accounts for between 3.32 and 12.88 percent of the cost inefficiency on average for all farms and between 13.24 and 28.45 percent of the cost inefficiency for those impacted with the inclusion of downside risk.

As presented in Table 6.2, results indicate revenue efficiency scores were higher than the cost efficiency scores. The number of revenue efficient farms ranged from 38 to 55 out of 256 farms each year, and the average efficiency ranged from 71.91 to 78.47 percent. The inclusion of variability in output as a risk measure increased the number of efficient farms to range from 63 to 92 per year and average efficiency to 80.03 to 86.70 percent. The inclusion of downside risk increased the number of efficient farms to range from 49 to 69 per year and the average efficiency scores ranged from 74.51 to 80.57 percent each year.

Efficient farms were located in all three regions of Kansas: east, central, and west. The distribution of more efficient farms in the east is as expected with 144 of the 256 farms being located in the eastern portion of Kansas. The remaining farms were divided among the central and western regions with 89 and 23 farms, respectively.

Table 6.1: Average Cost (Economic) Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
	Average	0.6325	0.7075	0.6914	0.6534	0.7193	0.6769	0.6844	0.6450
Cost (Economic) Efficiency	Std Dev.	0.1468	0.1386	0.1443	0.1500	0.1493	0.1496	0.1527	0.1451
	Minimum	0.2445	0.3040	0.2881	0.2664	0.2607	0.2135	0.1834	0.2423
	Number equal to one	12	13	10	10	13	10	10	8
	Number equal to one from East	9	7	7	7	9	8	9	7
	Number equal to one from Central	1	4	3	2	2	2	1	1
	Number equal to one from West	2	2	0	1	2	0	0	0
Cost (Economic) Efficiency with	Average	0.6846	0.7235	0.7563	0.7073	0.7623	0.7355	0.7137	0.6770
Variability in Outputs	Std Dev.	0.1646	0.1480	0.1552	0.1750	0.1679	0.1707	0.1688	0.1722
	Minimum	0.2928	0.3040	0.3584	0.2920	0.2607	0.2135	0.1834	0.2423
	Number equal to one	28	26	31	30	39	34	25	30
	Number equal to one from East	19	16	21	20	26	22	16	23
	Number equal to one from Central	6	8	8	9	10	12	9	7
	Number equal to one from West	3	2	2	1	3	0	0	0
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.1418	0.0548	0.2101	0.1555	0.1532	0.1814	0.0927	0.0902
Number of Farms Impacted by Inclusion of Risk		164	66	191	182	185	185	109	147
Portion of Inefficiency Attributed to Variability in Outputs if Impacted	Average	0.2461	0.2717	0.3169	0.2725	0.2968	0.3173	0.2808	0.2427
Cost (Economic) Efficiency with	Average	0.6447	0.7192	0.7176	0.6980	0.7437	0.7060	0.7062	0.6788
Downside Risk	Std Dev.	0.1584	0.1444	0.1560	0.1642	0.1594	0.1655	0.1643	0.1618
	Minimum	0.2445	0.3040	0.2881	0.2664	0.2607	0.2355	0.1834	0.2423
	Number equal to one	17	20	21	20	29	24	18	18
	Number equal to one from East	11	11	11	11	18	15	14	11
	Number equal to one from Central	4	5	7	7	8	7	3	5
	Number equal to one from West	2	4	3	2	3	2	1	2
Portion of Inefficiency Attributed to Downside Risk	Average	0.0332	0.0400	0.0849	0.1288	0.0871	0.0903	0.0689	0.0952
Number of Farms Impacted by Inclusion of Risk		68	106	103	164	108	156	125	110
Portion of Inefficiency Attributed to Downside Risk if Impacted	Average	0.1850	0.1324	0.2845	0.2357	0.2763	0.2167	0.2162	0.2657

Table 6.2: Average Revenue (Economic) Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
	Average	0.7525	0.7807	0.7847	0.7544	0.7834	0.7562	0.7577	0.7191
Revenue (Economic) Efficiency	Std Dev.	0.1822	0.1606	0.1647	0.1832	0.1773	0.1836	0.1730	0.1784
	Minimum	0.2367	0.2991	0.4170	0.1916	0.3224	0.0766	0.1662	0.2960
	Number equal to one	41	44	50	49	55	48	38	41
	Number equal to one from East	24	29	29	31	43	31	25	31
	Number equal to one from Central	13	10	14	13	8	11	7	6
	Number equal to one from West	4	5	7	5	4	6	6	4
Revenue (Economic) Efficiency with	Average	0.8444	0.8331	0.8556	0.8378	0.8670	0.8255	0.8340	0.8003
Variability in Outputs	Std Dev.	0.1510	0.1470	0.1435	0.1589	0.1482	0.1694	0.1566	0.1666
	Minimum	0.3595	0.3036	0.4644	0.2226	0.4061	0.0766	0.1931	0.3494
	Number equal to one	72	64	84	76	92	75	67	63
	Number equal to one from East	39	40	52	48	62	46	42	41
	Number equal to one from Central	27	18	20	23	24	23	19	17
	Number equal to one from West	6	6	12	5	6	6	6	5
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.3713	0.2389	0.3291	0.3394	0.3860	0.2843	0.3149	0.2891
Number of Farms Impacted by Inclusion of Risk		183	167	194	191	183	182	186	188
Portion of Inefficiency Attributed to Variability in Outputs if Impacted	Average	0.5596	0.3362	0.4196	0.4268	0.4904	0.3928	0.4048	0.3720
Revenue (Economic) Efficiency with	Average	0.7620	0.7991	0.8057	0.7831	0.7985	0.7824	0.7725	0.7451
Downside Risk	Std Dev.	0.1859	0.1636	0.1708	0.1874	0.1804	0.1909	0.1778	0.1862
	Minimum	0.2367	0.2991	0.4170	0.1916	0.3224	0.0769	0.1662	0.2960
	Number equal to one	49	55	69	65	68	67	52	53
	Number equal to one from East	28	31	37	40	49	40	33	36
	Number equal to one from Central	16	18	24	18	14	21	12	13
	Number equal to one from West	5	6	8	7	5	6	7	4
Portion of Inefficiency Attributed to Downside Risk	Average	0.0386	0.0837	0.0978	0.1168	0.0697	0.1077	0.0614	0.0925
Number of Farms Impacted by Inclusion of Risk		54	86	99	137	78	128	79	76
Portion of Inefficiency Attributed to Downside Risk if Impacted	Average	0.2950	0.2827	0.3336	0.2830	0.2985	0.2791	0.3223	0.3524

The percent of cost efficient farms in the eastern region ranged from 4.86 to 6.25 percent without risk, 11.11 to 18.06 percent with variability in output, and 7.64 to 12.50 percent with downside risk each year. The percent of revenue efficient farms in the eastern region ranged from 16.67 to 29.86 percent without risk, 27.08 to 43.06 percent with variability in output, and 19.44 to 34.03 percent with downside risk each year.

The percent of cost efficient farms in the central region ranged from 1.12 to 4.49 percent without risk, 6.74 to 13.48 percent with variability in output, and 3.37 to 8.99 percent with downside risk each year. The percent of revenue efficient farms in the central region ranged from 6.74 to 15.73 percent without risk, 19.10 to 30.34 percent with variability in output, and 13.48 to 26.97 percent with downside risk each year.

The percent of cost efficient farms in the western region ranged from 0.00 to 8.70 percent without risk, 0.00 to 13.04 percent with variability in output, and 4.34 to 17.39 percent with downside risk each year. The percent of revenue efficient farms in the western region of Kansas ranged from 17.39 to 30.43 percent without risk, 21.74 to 52.17 percent with variability in output, and 17.39 to 34.78 percent with downside risk each year.

Table 6.3 and Table 6.4 illustrate the overall cost and overall revenue efficiency measures, respectively. The overall efficiency scores are calculated under constant returns to scale. The additional constraint results in fewer farms deemed efficient. The average overall cost efficiency each year ranged from 0.5342 to 0.6412 improving to 0.5947 to 0.6817 and 0.5399 to 0.6566 with the inclusion of risk as variability in outputs and downside risk, respectively. The average overall revenue efficiency each year ranged from 0.6662 to 0.7422 and risk, measured as the variability in outputs, explained between 3.62 and 15.33 percent of the overall revenue efficiency increasing the average overall revenue efficiency to a range of 0.7399

Table 6.3: Average Cost-Based Overall Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Cost Overall Efficiency	Average	0.5342	0.6206	0.6241	0.5457	0.6360	0.5969	0.6412	0.5733
	Std Dev.	0.1547	0.1568	0.1622	0.1651	0.1728	0.1677	0.1662	0.1663
	Minimum	0.1921	0.2016	0.2002	0.1409	0.1954	0.0398	0.0567	0.0183
	Number equal to one	3	4	6	3	3	3	5	3
Cost Overall Efficiency with Variability in Outputs	Average	0.5947	0.6343	0.6817	0.5979	0.6815	0.6552	0.6587	0.5949
	Std Dev.	0.1774	0.1689	0.1791	0.1983	0.1966	0.1960	0.1784	0.1901
	Minimum	0.2131	0.2016	0.2274	0.1409	0.2000	0.0398	0.0567	0.0183
	Number equal to one	12	12	19	15	22	17	12	13
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.1299	0.0362	0.1533	0.1150	0.1250	0.1446	0.0487	0.0506
Cost Overall Efficiency with Downside Risk	Average	0.5399	0.6257	0.6360	0.5743	0.6407	0.6133	0.6566	0.5777
	Std Dev.	0.1643	0.1606	0.1707	0.1857	0.1763	0.1848	0.1767	0.1720
	Minimum	0.1921	0.2016	0.2002	0.1409	0.1954	0.0398	0.0567	0.0183
	Number equal to one	7	8	9	8	7	8	9	5
Portion of Inefficiency Attributed to Downside Risk	Average	0.0121	0.0134	0.0317	0.0630	0.0127	0.0408	0.0431	0.0104

Table 6.4: Average Revenue-Based Overall Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Revenue Overall Efficiency	Average	0.6899	0.7251	0.7422	0.6991	0.7349	0.7156	0.7074	0.6662
	Std Dev.	0.1725	0.1553	0.1672	0.1781	0.1772	0.1831	0.1755	0.1806
	Minimum	0.2310	0.2791	0.3138	0.1819	0.2716	0.0727	0.1549	0.2327
	Number equal to one	18	22	33	26	32	22	17	22
Revenue Overall Efficiency with Variability in Outputs	Average	0.7798	0.7749	0.8127	0.7885	0.8275	0.7853	0.7774	0.7399
	Std Dev.	0.1569	0.1481	0.1536	0.1659	0.1608	0.1725	0.1664	0.1736
	Minimum	0.3084	0.2883	0.3474	0.2053	0.3370	0.0727	0.1572	0.2327
	Number equal to one	37	32	52	45	62	44	33	37
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.2899	0.1810	0.2736	0.2970	0.3495	0.2451	0.2392	0.2206
Revenue Overall Efficiency with Downside Risk	Average	0.6995	0.7436	0.7590	0.7243	0.7448	0.7325	0.7245	0.6871
	Std Dev.	0.1792	0.1636	0.1759	0.1888	0.1814	0.1942	0.1840	0.1910
	Minimum	0.2310	0.2791	0.3138	0.1819	0.2716	0.0727	0.1549	0.2327
	Number equal to one	26	32	48	39	37	41	31	30
Portion of Inefficiency Attributed to Downside Risk	Average	0.0307	0.0671	0.0653	0.0836	0.0374	0.0595	0.0582	0.0625

to 0.8275. The consideration of downside risk increased revenue-based overall efficiency to 0.6871 to 0.7590.

Cost- and revenue-based technical efficiency measures are presented in Table 6.5 and Table 6.6, respectively. Both measures indicate a large number of farms are technically efficient. Fewer differences are observed between the cost- and revenue-based measures for technical efficiency than for the other efficiency measures. The average cost-based technical efficiency ranged from 0.8113 to 0.8613 and between 61 and 83 farms were efficient each year. Almost 40 percent of the farms in the sample were cost-based technically efficient when adjusting for risk as variability in outputs. The average cost-based technical efficiency increased to between 0.8422 and 0.8963 each year considering variability in outputs and 0.8335 to 0.8784 each year when considering downside risk. The average revenue-based technical efficiency increased from 0.7904 to 0.8444 per year to between 0.8503 and 0.9032 and from 0.8119 to 0.8586 per year with variability in outputs and downside risk, respectively.

Table 6.7 and Table 6.8 characterize the efficiency scores for cost- and revenue-based allocative efficiencies. On average the farms cost-based allocatively efficiency ranged from 0.7558 to 0.8406 and revenue-based allocative efficiency ranged from 0.9153 to 0.9354. Variability in outputs and downside risk failed to account for the average inefficiency in some years. In some instances, allocative efficiency deteriorated with the inclusion on risk. There is nothing *a priori* that indicates efficiency should increase with the inclusion of additional variables. The percent of cost-based allocative efficiency explained by variability in outputs ranged from -3.33 to 22.92 percent each year and the percent explained by downside risk ranged from -1.08 to 12.94 percent each year. Variability in outputs accounted for between 30.53 and 54.30 percent of the revenue-based allocative inefficiency and downside risk accounted for

Table 6.5: Average Cost-Based Technical Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
	Average	0.8429	0.8543	0.8613	0.8380	0.8596	0.8392	0.8202	0.8113
Cost Technical Efficiency	Std Dev.	0.1494	0.1337	0.1374	0.1478	0.1435	0.1536	0.1596	0.1541
	Minimum	0.4200	0.4900	0.4700	0.4500	0.3800	0.2800	0.2400	0.3600
	Number equal to one	77	76	83	78	82	82	61	66
Cost Technical Efficiency with	Average	0.8753	0.8741	0.8894	0.8661	0.8963	0.8687	0.8577	0.8422
Variability in Outputs	Std Dev.	0.1404	0.1298	0.1304	0.1447	0.1365	0.1513	0.1566	0.1547
	Minimum	0.4400	0.5300	0.4900	0.4500	0.3800	0.2800	0.2400	0.3700
	Number equal to one	98	94	111	100	122	110	92	91
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.2066	0.1359	0.2023	0.1729	0.2612	0.1834	0.2084	0.1638
Cost Technical Efficiency with	Average	0.8542	0.8694	0.8784	0.8616	0.8757	0.8617	0.8352	0.8335
Downside Risk	Std Dev.	0.1498	0.1339	0.1365	0.1474	0.1402	0.1534	0.1585	0.1542
	Minimum	0.4200	0.4900	0.4700	0.4500	0.3800	0.2900	0.2400	0.3600
	Number equal to one	87	89	100	98	96	101	76	80
Portion of Inefficiency Attributed to Downside Risk	Average	0.0723	0.1035	0.1234	0.1457	0.1146	0.1402	0.0834	0.1176

Table 6.6: Average Revenue-Based Technical Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Revenue Technical Efficiency	Average	0.8241	0.8352	0.8415	0.8172	0.8444	0.8238	0.8127	0.7904
	Std Dev.	0.1696	0.1518	0.1554	0.1690	0.1623	0.1708	0.1650	0.1723
	Minimum	0.3717	0.4000	0.4444	0.4167	0.3571	0.0783	0.1733	0.2959
	Number equal to one	76	75	80	77	82	82	61	66
Revenue Technical Efficiency with Variability in Outputs	Average	0.8797	0.8720	0.8892	0.8679	0.9032	0.8707	0.8698	0.8503
	Std Dev.	0.1376	0.1346	0.1320	0.1485	0.1345	0.1557	0.1479	0.1532
	Minimum	0.4425	0.4237	0.4695	0.4762	0.4065	0.0783	0.2012	0.3497
	Number equal to one	97	94	111	100	122	112	92	91
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.3163	0.2234	0.3006	0.2771	0.3775	0.2660	0.3049	0.2857
Revenue Technical Efficiency with Downside Risk	Average	0.8350	0.8530	0.8586	0.8408	0.8569	0.8456	0.8267	0.8119
	Std Dev.	0.1715	0.1519	0.1560	0.1716	0.1617	0.1724	0.1657	0.1728
	Minimum	0.3717	0.4000	0.4444	0.4167	0.3571	0.0783	0.1733	0.2959
	Number equal to one	86	87	97	97	96	101	77	79
Portion of Inefficiency Attributed to Downside Risk	Average	0.0617	0.1079	0.1077	0.1293	0.0804	0.1235	0.0748	0.1027

Table 6.7: Average Cost-Based Allocative Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
	Average	0.7558	0.8304	0.8057	0.7832	0.8387	0.8099	0.8406	0.8028
Cost Allocative Efficiency	Std Dev.	0.1317	0.1089	0.1196	0.1249	0.1103	0.1136	0.1211	0.1344
	Minimum	0.3569	0.4471	0.3694	0.2664	0.3811	0.3201	0.2713	0.3797
	Number equal to one	12	13	10	10	13	10	10	8
Cost Allocative Efficiency with Variability in Outputs	Average	0.7848	0.8281	0.8502	0.8154	0.8488	0.8465	0.8352	0.8077
	Std Dev.	0.1412	0.1142	0.1155	0.1318	0.1193	0.1187	0.1298	0.1459
	Minimum	0.3619	0.4471	0.4821	0.2920	0.4091	0.3170	0.2713	0.3797
	Number equal to one	28	26	31	30	39	34	25	30
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.1189	-0.0132	0.2292	0.1483	0.0628	0.1923	-0.0333	0.0247
Cost Allocative Efficiency with Downside Risk	Average	0.7587	0.8286	0.8180	0.8113	0.8490	0.8205	0.8487	0.8180
	Std Dev.	0.1380	0.1103	0.1232	0.1273	0.1120	0.1213	0.1211	0.1306
	Minimum	0.3569	0.4471	0.3694	0.2664	0.3811	0.3201	0.2713	0.3797
	Number equal to one	17	20	21	20	29	24	18	18
Portion of Inefficiency Attributed to Downside Risk	Average	0.0122	-0.0108	0.0636	0.1294	0.0636	0.0558	0.0513	0.0768

Table 6.8: Average Revenue-Based Allocative Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Revenue Allocative Efficiency	Average	0.9153	0.9354	0.9336	0.9237	0.9291	0.9207	0.9353	0.9160
	Std Dev.	0.1186	0.0912	0.0944	0.1137	0.1111	0.1240	0.1097	0.1300
	Minimum	0.2367	0.5997	0.4445	0.4081	0.4860	0.3989	0.4268	0.4005
	Number equal to one	41	44	50	49	55	48	38	41
Revenue Allocative Efficiency with Variability in Outputs	Average	0.9598	0.9552	0.9621	0.9651	0.9598	0.9485	0.9594	0.9425
	Std Dev.	0.0778	0.0781	0.0693	0.0772	0.0757	0.0955	0.0788	0.0985
	Minimum	0.3595	0.6216	0.5118	0.4674	0.5805	0.4741	0.5956	0.4473
	Number equal to one	72	64	84	76	92	75	67	63
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.5259	0.3053	0.4288	0.5430	0.4337	0.3509	0.3725	0.3151
Revenue Allocative Efficiency with Downside Risk	Average	0.9144	0.9369	0.9383	0.9312	0.9321	0.9264	0.9364	0.9214
	Std Dev.	0.1193	0.0911	0.0938	0.1095	0.1099	0.1216	0.1090	0.1264
	Minimum	0.2367	0.5706	0.4445	0.4081	0.4791	0.4003	0.4268	0.3997
	Number equal to one	49	55	69	65	68	67	52	53
Portion of Inefficiency Attributed to Downside Risk	Average	-0.0109	0.0224	0.0717	0.0987	0.0427	0.0720	0.0164	0.0642

between -1.09 and 9.87 percent of the revenue-based allocative inefficiency. The number of cost-based allocatively efficient farms increased from 8 to 10 per year to 25 to 39 per year with variability in outputs and 17 to 29 per year with downside risk. The number of revenue-based allocatively efficient farms increased from between 38 to 55 per year to between 63 to 92 per year with variability in outputs and between 49 to 69 per year with downside risk.

Scale efficiency is illustrated in Table 6.9 for cost-based scale efficiency and Table 6.10 for revenue-based scale efficiency. In some years, the average scale efficiency deteriorated with the inclusion of risk. There is nothing that requires the efficiency to increase with the inclusion of the risk constraints. The average cost-based scale efficiency was between 0.8332 and 0.9309. The number of cost-based scale efficient farms increased from between 3 to 6 up to between 12 and 22 with the inclusion of variability in outputs and between 5 and 9 with the inclusion of downside risk. The average revenue-based scale efficiency ranged from 0.9255 to 0.9468. The number of revenue-based scale efficient farms increased from 17 to 33 per year to between 32 and 62 per year with variability in outputs and between 27 and 48 per year with downside risk.

The results above illustrate differences in efficiency measures without risk and including the two different risk measures. It is of interest to examine the relationship between the two risk measures and their impact on efficiency scores. Table 6.11 shows the correlation coefficients between the ten efficiency measures with risk represented as variability in outputs and the corresponding efficiency measure with risk represented as downside risk for each of the eight years considered. For example, the value in the upper left hand corner of Table 6.11, 0.8195, is the correlation between cost efficiency with variability in outputs and cost efficiency with downside risk in 2003. The value in the bottom right hand corner, 0.8787, is the correlation between revenue-based scale efficiency with variability in outputs and revenue-based scale

Table 6.9: Average Cost-Based Scale Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Cost Scale Efficiency	Average	0.8437	0.8749	0.8979	0.8332	0.8784	0.8749	0.9309	0.8826
	Std Dev.	0.1344	0.1231	0.1071	0.1554	0.1226	0.1268	0.1066	0.1368
	Minimum	0.3422	0.3018	0.3919	0.2188	0.2331	0.1866	0.2091	0.0429
	Number equal to one	3	4	6	3	3	3	5	3
Cost Scale Efficiency with Variability in Outputs	Average	0.8657	0.8739	0.8971	0.8389	0.8860	0.8813	0.9199	0.8735
	Std Dev.	0.1309	0.1284	0.1177	0.1565	0.1252	0.1297	0.1166	0.1435
	Minimum	0.3539	0.3018	0.2274	0.2188	0.2402	0.1866	0.2091	0.0429
	Number equal to one	12	12	19	15	22	17	12	13
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.1413	-0.0076	-0.0077	0.0339	0.0628	0.0509	-0.1583	-0.0778
Cost Scale Efficiency with Downside Risk	Average	0.8378	0.8689	0.8847	0.8204	0.8592	0.8616	0.9252	0.8536
	Std Dev.	0.1389	0.1275	0.1222	0.1653	0.1347	0.1339	0.1152	0.1524
	Minimum	0.2608	0.3018	0.2810	0.2133	0.1954	0.1692	0.2091	0.0183
	Number equal to one	7	8	9	8	7	8	9	5
Portion of Inefficiency Attributed to Downside Risk	Average	-0.0376	-0.0473	-0.1294	-0.0769	-0.1573	-0.1069	-0.0817	-0.2474

Table 6.10: Average Revenue-Based Scale Efficiency Measures for Sample of Kansas Farms, 2003-2010

		2003	2004	2005	2006	2007	2008	2009	2010
Revenue Scale Efficiency	Average	0.9255	0.9342	0.9466	0.9317	0.9415	0.9468	0.9386	0.9292
	Std Dev.	0.1131	0.0979	0.0816	0.1010	0.0950	0.0795	0.1093	0.1138
	Minimum	0.3011	0.3785	0.4616	0.3110	0.3616	0.3488	0.1549	0.3659
	Number equal to one	20	22	33	26	32	23	17	30
Revenue Scale Efficiency with Variability in Outputs	Average	0.9274	0.9340	0.9491	0.9431	0.9545	0.9517	0.9355	0.9270
	Std Dev.	0.1048	0.0959	0.0750	0.0949	0.0829	0.0730	0.1068	0.1114
	Minimum	0.3084	0.3859	0.5023	0.3700	0.4340	0.6014	0.1572	0.4207
	Number equal to one	37	32	52	45	62	44	35	38
Portion of Inefficiency Attributed to Variability in Outputs	Average	0.0249	-0.0037	0.0477	0.1669	0.2228	0.0926	-0.0511	-0.0322
Revenue Scale Efficiency with Downside Risk	Average	0.9258	0.9344	0.9422	0.9278	0.9362	0.9376	0.9417	0.9245
	Std Dev.	0.1134	0.0964	0.0858	0.1016	0.0990	0.0933	0.1106	0.1183
	Minimum	0.3011	0.3785	0.4616	0.3110	0.3616	0.1914	0.1549	0.3659
	Number equal to one	27	32	48	39	37	41	31	35
Portion of Inefficiency Attributed to Downside Risk	Average	0.0035	0.0029	-0.0829	-0.0577	-0.0903	-0.1711	0.0510	-0.0676

efficiency with downside risk in 2010. In most cases, high positive correlation was observed between the efficiency scores with the alternative risk measure. This is as expected. The two risk measures chosen, variability in outputs and downside risk, are measuring risk in different ways, but the overall impact of their inclusion is similar.

Table 6.11: Correlations among Efficiency Scores with Different Risk Measures, 2003-2010

Efficiency Measure		2003	2004	2005	2006	2007	2008	2009	2010
		Downside Risk							
CE	Variability	0.8195	0.8708	0.7701	0.7832	0.8622	0.8747	0.8786	0.8279
RE	Variability	0.7785	0.8173	0.8219	0.8406	0.8419	0.8753	0.8041	0.8145
COE	Variability	0.8300	0.9293	0.9112	0.8695	0.9409	0.9213	0.9621	0.9613
ROE	Variability	0.8159	0.8497	0.8493	0.8399	0.8548	0.8926	0.8744	0.8772
CTE	Variability	0.8333	0.8894	0.8716	0.8566	0.8612	0.9012	0.8697	0.8731
RTE	Variability	0.8178	0.8490	0.8410	0.8529	0.8637	0.8815	0.8371	0.8547
CAE	Variability	0.7178	0.7675	0.6899	0.7864	0.8024	0.7640	0.8068	0.7985
RAE	Variability	0.7224	0.7654	0.7634	0.7775	0.8100	0.8998	0.7352	0.8340
CSE	Variability	0.8390	0.9472	0.8539	0.9140	0.9217	0.9197	0.8877	0.9050
RSE	Variability	0.7925	0.9253	0.7686	0.8543	0.8701	0.7744	0.8765	0.8787

All ten efficiency measures were addressed above. The following section will focus more thoroughly on the results for cost and revenue economic efficiency with the two risk measures.

6.2 Cost- and Revenue-Based Economic Efficiency Measures, 2003-2010

The correlation coefficients observed for the economic efficiency measures ranged from about 0.77 to 0.88. An obvious question is whether risk is impacting the efficiency of the same farms. Figure 6.1 provides an illustration of the cost efficiency of farms in 2010 without risk and the changes observed with the inclusion of each risk measure. The diagonal line is formed from the initial efficiency scores of the farms. The green and purple markers represent the new efficiency scores with the inclusion of variability in outputs or downside risk, respectively. It is evident that risk as measured in this analysis does not improve the efficiency scores for a number of farms. The farms that are experiencing an improved efficiency score when risk is accounted for are not necessarily the same farms. This will be explored further below.

Figure 6.1: Cost Efficiency with and without Risk Measures, 2010

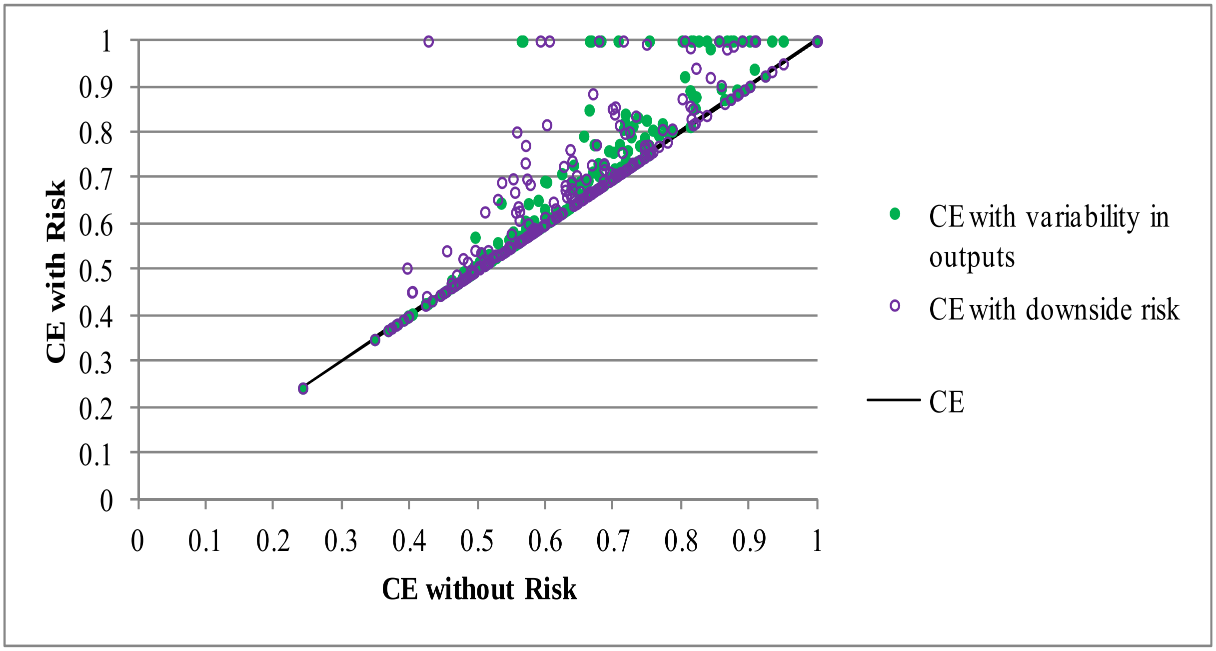


Figure 6.2 illustrates revenue efficiency for 2010 with and without the risk measures. The results are similar to those found for Figure 6.1. More farms are improving their efficiency score especially with risk measured as the variability in outputs, but there are still a number of farms that experience no improvement with the inclusion of risk. In other words, their inefficiency is not attributed to risk, at least not risk as measured in this analysis. Additionally, the farms that are experiencing an increase in efficiency are not seeing the same improvements under each risk measure.

Figure 6.2: Revenue Efficiency with and without Risk Measures, 2010

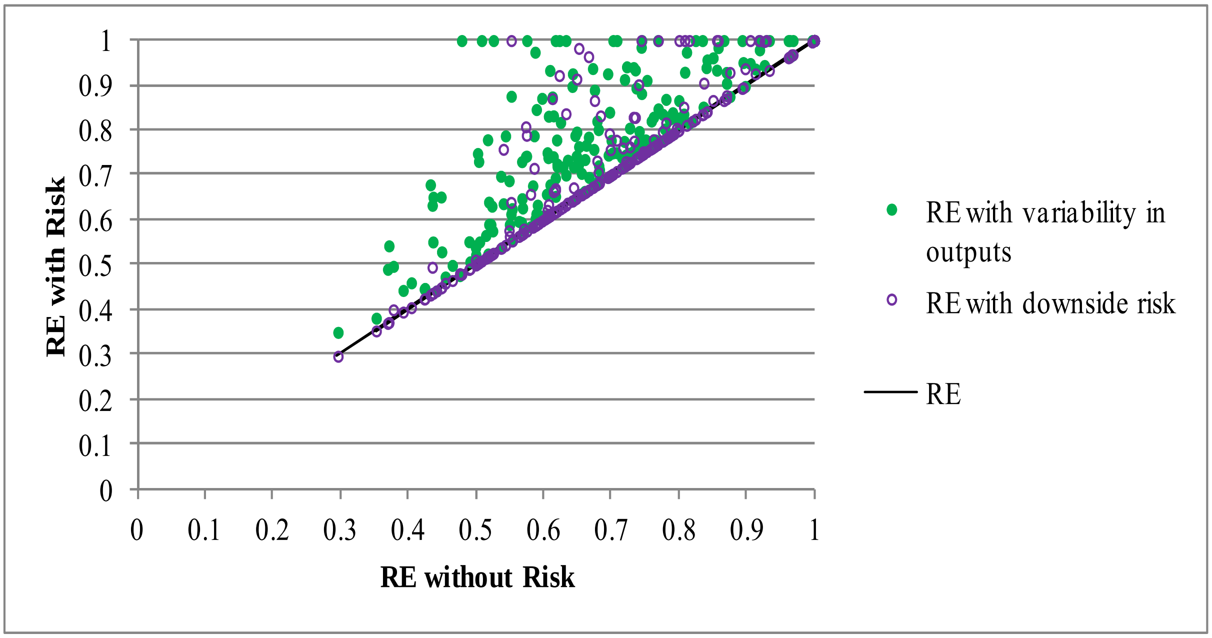


Table 6.12 through Table 6.19 below represent the correlation coefficients among the cost and revenue efficiency scores without risk and with each risk measure for the eight years of efficiency calculations. Higher correlations were observed among the cost efficiency scores with and without risk and among the revenue efficiency scores with and without risk than between cost and revenue measures. This is as expected because cost efficiency focuses on the choice of inputs with given output levels while revenue efficiency focuses on the optimal choice of outputs given inputs. The higher correlations observed between the efficiency measures without risk and efficiency measures with downside risk further correspond to the results in Table 6.1 and Table 6.2 where it was observed that the number of efficient farms and the efficiency scores were improving on average with the adjustment for risk, but the improvements were less than what was observed when risk was accounted for using the variability in outputs.

Table 6.12: Correlations among Efficiency Scores, 2003

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.8518	1.0000				
CE with downside risk	0.9611	0.8195	1.0000			
RE	0.3811	0.4276	0.3862	1.0000		
RE with variability	0.4026	0.5216	0.3951	0.8013	1.0000	
RE with downside risk	0.3574	0.4082	0.3864	0.9843	0.7785	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.13: Correlations among Efficiency Scores, 2004

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.9091	1.0000				
CE with downside risk	0.9616	0.8708	1.0000			
RE	0.6965	0.6566	0.6924	1.0000		
RE with variability	0.6242	0.6757	0.6167	0.8553	1.0000	
RE with downside risk	0.6700	0.6263	0.7081	0.9535	0.8149	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.14: Correlations among Efficiency Scores, 2005

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.8289	1.0000				
CE with downside risk	0.9178	0.7701	1.0000			
RE	0.5742	0.6311	0.5812	1.0000		
RE with variability	0.5341	0.7260	0.5318	0.8643	1.0000	
RE with downside risk	0.5570	0.6064	0.6253	0.9517	0.8219	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.15: Correlations among Efficiency Scores, 2006

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.8606	1.0000				
CE with downside risk	0.9068	0.7832	1.0000			
RE	0.5253	0.4778	0.5317	1.0000		
RE with variability	0.5775	0.6662	0.5655	0.8579	1.0000	
RE with downside risk	0.5168	0.4790	0.5972	0.9584	0.8406	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.16: Correlations among Efficiency Scores, 2007

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.9161	1.0000				
CE with downside risk	0.9339	0.8622	1.0000			
RE	0.6508	0.5873	0.5998	1.0000		
RE with variability	0.6288	0.7048	0.5839	0.8565	1.0000	
RE with downside risk	0.6393	0.5889	0.6368	0.9660	0.8419	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.17: Correlations among Efficiency Scores, 2008

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.8941	1.0000				
CE with downside risk	0.9457	0.8747	1.0000			
RE	0.5987	0.6265	0.5709	1.0000		
RE with variability	0.6265	0.7387	0.6087	0.8804	1.0000	
RE with downside risk	0.5963	0.6534	0.6090	0.9450	0.8753	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.18: Correlations among Efficiency Scores, 2009

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.9050	1.0000				
CE with downside risk	0.9644	0.8786	1.0000			
RE	0.6618	0.5933	0.6587	1.0000		
RE with variability	0.6031	0.6389	0.6095	0.8199	1.0000	
RE with downside risk	0.6490	0.5906	0.6762	0.9732	0.8041	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.19: Correlations among Efficiency Scores, 2010

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
CE	1.0000					
CE with variability	0.9245	1.0000				
CE with downside risk	0.8936	0.8279	1.0000			
RE	0.5237	0.4752	0.5390	1.0000		
RE with variability	0.5092	0.5813	0.5306	0.8279	1.0000	
RE with downside risk	0.5031	0.4569	0.5983	0.9341	0.8145	1.0000

Note: Variability is the standard deviation of crop and livestock outputs and downside risk is the weighted summation of net farm income unable to cover unpaid labor expenses.

Table 6.20 examines the summary statistics for the efficient farms compared to the average for all farms and among each other. To be included in Table 6.20, a farm must be efficient (have an efficiency score of 1) for the respective measure in a particular year. A farm could potentially be included up to 8 times for each measure if they were efficient every year. The efficient farms had significantly larger and different inputs and outputs than the average with the exception of livestock inputs and outputs for the revenue efficient farms with and without an adjustment for risk. The efficient farms were significantly larger than average in terms of value of farm production, net farm income, and total acres. The cost efficient farms devoted less time to crop production and more time to livestock production. The revenue efficient farms with the exception of revenue efficiency with variability devoted more time to crop production than the average for the sample and the cost efficient farms. With the exception of cost efficiency with downside risk, the efficient farms had significantly higher profit margin, asset turnover, and rate of return on investment ratios than the average.

Table 6.20: Summary Statistics for Efficient Farms, 2003-2010

	Average for all farms	CE	CE with variability in outputs	CE with downside risk	RE	RE with variability in outputs	RE with downside risk
Inputs							
Labor	1.33[ad]	1.94[b]	1.74[b]	1.57[bcde]	1.50[cde]	1.42[de]	1.48[e]
Crop	129,427[a]	232,694[b]	192,114[b]	167,245[bc]	177,534[bc]	153,507[c]	173,462[bc]
Fuel	33,486[a]	61,609[b]	49,570[bc]	45,824[bcd]	43,964[cd]	38,621[d]	41,279[d]
Livestock	15,226[a]	79,327[b]	40,490[c]	49,648[bc]	23,190[a]	21,502[a]	20,323[a]
Capital	208,303[a]	334,654[b]	283,213[bd]	265,529[bcd]	263,631[bcd]	238,042[cd]	254,088[d]
Outputs							
Crop	383,875[a]	763,765[be]	597,633[bcde]	557,207[cde]	616,238[bce]	515,319[d]	585,866[e]
Livestock	42,707[a]	156,057[b]	104,384[c]	117,287[bc]	42,576[a]	48,365[a]	41,048[a]
Risk Measures							
Variability in Crop	85,779[a]	160,465[bd]	110,668[cd]	124,930[bcd]	135,363[bd]	105,041[c]	125,031[d]
Variability in Livestock	16,011[a]	43,190[b]	24,722[c]	30,448[bc]	16,633[a]	16,728[a]	15,786[a]
Downside Risk	14,943[a]	13,690[ac]	13,943[a]	8,264[b]	14,828[a]	14,630[a]	12,082[c]
Farm Characteristics							
Value of Farm Production	357,059[a]	739,566[b]	585,239[bce]	555,553[cde]	540,669[ce]	464,757[de]	518,744[e]
Net Farm Income	94,813[a]	268,810[b]	197,102[c]	202,891[bc]	179,321[c]	150,270[d]	173,292[c]
Feed Grain Income	108,812[a]	285,390[b]	206,835[bce]	186,252[bcde]	193,899[ce]	157,077[de]	182,013[e]
Hay and Forage Income	11,573[a]	17,261[ab]	13,687[ab]	15,995[ab]	23,425[b]	17,977[ab]	19,816[ab]
Oilseed Income	90,273[a]	222,789[b]	161,042[bc]	142,389[bc]	154,322[bc]	126,684[c]	143,911[c]
Small Grains Income	62,965[a]	73,341[a]	71,961[a]	75,653[a]	68,489[a]	66,961[a]	71,809[a]
Beef Income	39,235[a]	144,736[b]	97,150[b]	109,418[b]	39,280[a]	44,491[a]	38,041[a]
Dairy Income	87[a]	4[b]	2[b]	2[b]	53[ab]	130[ab]	41[ab]
Swine Income	139[a]	0[b]	0[b]	5[b]	0[b]	0[b]	2[b]
Total Acres	1,933[a]	3,014[b]	2,586[b]	2,724[b]	2,144[c]	2,079[ac]	2,147[c]
Crop Labor Percentage	87.05%[a]	79.10%[b]	78.55%[b]	81.51%[b]	91.31%[c]	88.35%[a]	91.08%[c]
Diversification Index	0.2614[a]	0.2853[bc]	0.2754[bc]	0.2599[b]	0.2966[c]	0.2781[b]	0.2930[bc]
Financial Efficiency Ratios							
Profit Margin	0.0200[acd]	0.1686[bd]	0.0985[bcd]	0.0986[abcd]	0.0478[cd]	0.0560[cd]	0.0768[d]
Asset Turnover	0.3257[a]	0.3890[bcd]	0.3821[bcd]	0.3411[ab]	0.4055[cd]	0.3716[bd]	0.3955[d]
Rate of Return on Investment	0.0315[a]	0.0960[b]	0.0858[b]	0.0851[b]	0.0809[bc]	0.0661[c]	0.0799[b]
Number of Observations	2,048	86	243	167	366	593	478

Note: Unlike superscripts indicate the means are statistically different at the 5% level.

If farms are taking advantage of economies of scale, larger farms are expected to be more efficient than smaller farms. Table 6.21 divides the farms into four categories based on their value of farm production (VFP). T-tests were conducted to determine if the farms had statistically different efficiency scores among the VFP categories. The efficiency scores for the largest two VFP categories were higher than the $100,000 to $249,999 VFP category. An interesting result was the decrease in efficiency observed from the smallest VFP group (less than $100,000) and the next category ($100,000 to $249,999). One explanation for this result is the smallest farms may not be stand alone operations and are instead utilizing some machinery and/or labor from another farm. Table 6.21 also presents the number of farms efficient in all 8 years, at least 1 year, and 5 or more years for the efficiency measures and VFP. It is evident from these results that it is extremely difficult for a farm to remain efficient for an extended period of time.

Regression analysis was used to examine the impact of farm size, measured using average total assets, and time spent on crop production on cost and revenue efficiency. Both assets and assets squared were included to account for any non-linearity in the impact of farm size on efficiency. The values in Table 6.21 indicate that efficiency was initially decreasing with size followed by an increase. Regression analysis was also used to examine the impact of the five inputs used in the analysis on efficiency. A balanced panel of 256 farms over 8 years was used in the analysis. The random effects model was chosen over both ordinary least squares and fixed effects models. The Breusch-Pagan test was used to select random effects over ordinary least squares (Baltagi 2008). The Hausman test was used to select random effects over fixed effects (Baltagi 2008). The fixed effects model was preferred in several instances based on the Hausman test; however, a random effects model was used for each estimation to maintain consistency. Additionally, the random effects model uses less degrees of freedom and is more desirable when the data set is for a representative sample and the results are applicable to more than just the sample.

Table 6.21: Efficiency by Value of Farm Production (VFP) Category, 2003-2010

	Less than $100,000	$100,000 to $249,999	$250,000 to $499,999	$500,000 and more
Number of Farms	26	90	86	54
Average VFP	65,145[a]	178,239[b]	351,193[c]	804,986[d]
Average Cost Efficiency	0.6701[abc]	0.6378[a]	0.6869[b]	0.7265[c]
Number of Farms Efficient in All 8 Years	1	0	0	1
Number of Farms Efficient in at Least 1 Year	4	8	14	18
Number of Farms Efficient in 5 or More Years	2	0	0	2
Average Cost Efficiency with Variability	0.7080[abc]	0.6793[a]	0.7303[b]	0.7772[c]
Number of Farms Efficient in All 8 Years	2	0	0	2
Number of Farms Efficient in at Least 1 Year	11	29	37	33
Number of Farms Efficient in 5 or More Years	4	1	2	8
Average Cost Efficiency with Downside Risk	0.7088[ab]	0.6607[a]	0.7127[b]	0.7495[b]
Number of Farms Efficient in All 8 Years	1	1	0	2
Number of Farms Efficient in at Least 1 Year	6	13	20	22
Number of Farms Efficient in 5 or More Years	4	1	1	4
Average Revenue Efficiency	0.7631[ab]	0.6961[a]	0.7593[b]	0.8713[c]
Number of Farms Efficient in All 8 Years	3	2	0	2
Number of Farms Efficient in at Least 1 Year	19	32	34	44
Number of Farms Efficient in 5 or More Years	5	3	2	11
Average Revenue Efficiency with Variability	0.8570[ac]	0.7943[b]	0.8315[a]	0.9083[c]
Number of Farms Efficient in All 8 Years	4	2	0	2
Number of Farms Efficient in at Least 1 Year	23	57	62	50
Number of Farms Efficient in 5 or More Years	12	12	3	17
Average Revenue Efficiency with Downside Risk	0.7728[ab]	0.7133[a]	0.7837[b]	0.8938[c]
Number of Farms Efficient in All 8 Years	4	3	1	3
Number of Farms Efficient in at Least 1 Year	19	35	39	48
Number of Farms Efficient in 5 or More Years	8	7	6	21

Note: Unlike superscripts indicate the means are statistically different at the 5% level.

The results in Table 6.22 indicate total assets do not have a statistically significant effect on cost efficiency nor revenue efficiency with and without the inclusion of risk. An increase in the time devoted to crop production has a negative and significant effect on cost efficiency with and without risk, ceteris paribus. This indicates an increase in time devoted to livestock production may lead to an increase in cost efficiency. An increase in time devoted to crop production has a positive and significant effect on revenue efficiency without risk and adjusted for downside risk, and a positive but not statistically significant effect on variability adjusted revenue efficiency measures.

Table 6.22: Impact of Farm Size and Time Spent on Crop Production on Efficiency Scores

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
Intercept	0.850824***	0.905665***	0.855417***	0.690138***	0.824102***	0.704127***
	(0.028409)	(0.032264)	(0.030440)	(0.033868)	(0.030332)	(0.034718)
Assets	-0.001368	-0.000676	-0.000165	-0.000960	-0.000289	-0.000452
	(0.000846)	(0.000981)	(0.000882)	(0.001021)	(0.000941)	(0.001034)
$Assets^2$	0.000004	-0.000010	-0.000014	0.000008	-0.000001	-0.000001
	(0.000013)	(0.000015)	(0.000013)	(0.000016)	(0.000015)	(0.000016)
Crop Labor Percentage	-0.182348***	-0.201051***	-0.170200***	0.092797**	0.019263	0.094869**
	(0.030403)	(0.034566)	(0.032474)	(0.036273)	(0.032509)	(0.037154)
Overall R^2	0.0474	0.0318	0.0273	0.0239	0.0000	0.0272

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Assets are equal to total assets divided by 100,000.

Farm size and time spent on crop production were regressed on the differences between cost efficiency and each risk adjusted cost efficiency measure as well as the differences between revenue efficiency and each risk adjust revenue efficiency measure in Table 6.23. An increase in total assets would increase the difference between cost efficiency with and without variability up to a point before decreasing the difference between the measures. Time devoted to crop production had a negative and significant effect on the difference between revenue efficiency with and without variability and between the two risk adjusted revenue efficiency measures.

Table 6.23: Impact of Farm Size and Time Spent on Crop Production on Differences between Efficiency Scores

Difference between:	CE with and without variability	CE with and without downside risk	RE with and without variability	RE with and without downside risk	CE with variability and CE with downside risk	RE with variability and RE with downside risk
Intercept	0.042824***	0.012314	0.153010***	0.001239	0.041993**	0.147138***
	(0.014683)	(0.010601)	(0.018085)	(0.010235)	(0.018590)	(0.019686)
Assets	0.001030**	0.001051***	0.000434	0.000672**	0.000048	-0.000179
	(0.000471)	(0.000299)	(0.000549)	(0.000305)	(0.000568)	(0.000591)
$Assets^2$	-0.000019**	-0.000013***	-0.000010	-0.000008*	-0.000007	-0.000002
	(0.000008)	(0.000004)	(0.000009)	(0.000005)	(0.000009)	(0.000009)
Crop Labor Percentage	-0.008109	0.003887	-0.091613***	0.014300	-0.026111	-0.101406***
	(0.015728)	(0.011246)	(0.019374)	(0.010954)	(0.019920)	(0.021079)
Overall R^2	0.0044	0.001	0.0619	0.0053	0.0003	0.0664

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.
Assets are equal to total assets divided by 100,000.

Table 6.24 shows an increase in crop and livestock inputs has a positive and significant impact on cost and revenue efficiency with and without risk. An increase in fuel had a positive and significant effect on cost efficiency measures, but the coefficients were not significant for the revenue efficiency measures. The capital input had a negative and significant effect on cost efficiency measures. This may be related to the size of the farms or how efficiently they are using their capital inputs specifically. Revenue efficiency was statistically less responsive to changes in inputs.

Table 6.25 shows the relationship between the differences in the efficiency scores with and without risk and the risk adjusted efficiency scores and the inputs. Crop inputs had a positive and statistically significant effect on the difference between cost efficiency adjusted by variability in outputs and cost efficiency without risk. Crop inputs had a negative and statistically significant effect on the difference between revenue efficiency with variability in outputs and revenue efficiency. Fuel had a positive and significant effect on the difference between the two cost efficiency measures adjusted for risk. Capital had a negative and significant effect on the difference between cost efficiency with variability in outputs and cost efficiency without a risk adjustment.

Table 6.24: Impact of Inputs on Efficiency Scores

	CE	CE with variability	CE with downside risk	RE	RE with variability	RE with downside risk
Intercept	0.674262***	0.705981***	0.714818***	0.740194***	0.821684***	0.761953***
	(0.011524)	(0.012460)	(0.013259)	(0.013547)	(0.011474)	(0.014374)
Labor	-0.009620	-0.002796	-0.015488	-0.012082	-0.011256	-0.007048
	(0.008710)	(0.009794)	(0.009440)	(0.010436)	(0.009274)	(0.010787)
Crop Inputs	0.002090***	0.002647***	0.001859***	0.001998***	0.001458**	0.001758***
	(0.000542)	(0.000625)	(0.000568)	(0.000657)	(0.000603)	(0.000669)
Fuel	0.007510***	0.009783***	0.006571***	0.001172	0.002268	0.000098
	(0.001929)	(0.002234)	(0.002010)	(0.002344)	(0.002165)	(0.002377)
Livestock Inputs	0.007001***	0.006934***	0.006720***	0.004630***	0.003735***	0.004350***
	(0.001016)	(0.001154)	(0.001084)	(0.001224)	(0.001100)	(0.001256)
Capital	-0.002306***	-0.002872***	-0.002340***	0.000006	-0.000080	-0.000059
	(0.000467)	(0.000540)	(0.000487)	(0.000567)	(0.000523)	(0.000575)
Overall R^2	0.1094	0.0923	0.0731	0.0689	0.0358	0.0561

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively
Crop Inputs, Fuel, Livestock Inputs, and Capital were all divided by 10,000.

Table 6.25: Impact of Inputs on Differences between Efficiency Scores

Difference between:	CE with and without variability	CE with and without downside risk	RE with and without variability	RE with and without downside risk	CE with variability and CE with downside risk	RE with variability and RE with downside risk
Intercept	0.035622***	0.034631***	0.086620***	0.017245***	0.001351	0.068150***
	(0.005326)	(0.005009)	(0.007438)	(0.004265)	(0.007270)	(0.008334)
Labor	0.005907	-0.002761	-0.000894	0.005375*	0.007114	-0.006872
	(0.004498)	(0.003346)	(0.005713)	(0.003200)	(0.005730)	(0.006256)
Crop Inputs	0.000507*	-0.000048	-0.000751**	-0.000038	0.000520	-0.000633
	(0.000302)	(0.000195)	(0.000359)	(0.000198)	(0.000366)	(0.000388)
Fuel	0.001284	-0.000638	0.001205	-0.000814	0.002855**	0.002251
	(0.001093)	(0.000686)	(0.001281)	(0.000705)	(0.001310)	(0.001379)
Livestock Inputs	-0.000573	0.000023	-0.000623	-0.000452	-0.000213	-0.000205
	(0.000539)	(0.000378)	(0.000669)	(0.000373)	(0.000676)	(0.000729)
Capital	-0.000467*	-0.000132	-0.000128	-0.000024	-0.000410	-0.000092
	(0.000264)	(0.000166)	(0.000310)	(0.000171)	(0.000317)	(0.000334)
Overall R^2	0.0111	0.0091	0.0361	0.0056	0.0158	0.0216

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.
Crop Inputs, Fuel, Livestock Inputs, and Capital were all divided by 10,000.

6.3 Results for Whole-farm Analysis in 2008 with Risk Preference Score

This section of the results focuses on the separate data set for 2008 that includes the risk preference score generated by a survey conducted by Pope (2009). The values themselves are not comparable to the previous results because the data sets are different. Table 6.26 presents the average cost and revenue efficiencies for the 258 farms in the sample using the five inputs (labor, crop, fuel, livestock, and capital) and two outputs (crops and livestock) followed by the average cost and revenue efficiencies adjusted for risk preference. The inverse of the risk preference score was included as a non-discretionary input. Smaller risk preference values are indicative of more risk averse farmers, therefore, the inverse of the risk preference score was included to be consistent with the concept that "less is better" in terms of inputs in data envelopment analysis.

The average cost efficiency was 0.5691 and ranged from 0.5286 for the strongly risk averse farms to 0.6423 for the least risk averse (Table 6.26). The average difference in efficiency scores between the strongly risk averse and other risk preference farms was 0.1137. In terms of average costs, the consequence of additional risk aversion is $51,704. Similar to the previous results, revenue efficiency was higher on average than cost efficiency and ranged from 0.6419 for the 94 strongly risk averse farms to 0.7423 for those with other risk preferences. The average revenue efficiency was 0.6735. Over 40 percent of the farms experienced an increase in cost and revenue efficiency with the inclusion of their risk preference score as an input. For those impacted, the portion of inefficiency attributed to the risk preference score was 19.43 percent for cost efficiency and 17.78 percent for revenue efficiency (Table 6.26).

The number of cost efficient farms with a risk preference score of 21 or less (strongly risk averse) did not change and remained at 0 when the inverse risk preference score was considered in the efficiency estimates. The average cost and revenue efficiencies for the strongly risk averse

Table 6.26: Average Efficiency Measures for Sample of Kansas Farms, 2008

		Cost (Economic) Efficiency	Revenue (Economic) Efficiency
	Average	0.5691	0.6735
Efficiency	Std Dev.	0.1509	0.1939
	Minimum	0.2170	0.1842
	Number equal to one	6	31
	Average for strongly risk averse (94 farms)	0.5286	0.6419
	Number equal to one strongly risk averse	0	10
	Average for slightly risk averse (131 farms)	0.5798	0.6789
	Number equal to one slightly risk averse	3	17
	Average for all other risk preferences (33 farms)	0.6423	0.7423
	Number equal to one other risk preferences	3	4
Efficiency with inverse risk preference score (RPS)	Average	0.6043	0.6987
	Std Dev.	0.1444	0.1959
	Minimum	0.2432	0.1842
	Number equal to one	13	46
	Average for strongly risk averse (94 farms)	0.5286	0.6987
	Number equal to one strongly risk averse	0	10
	Average for slightly risk averse (131 farms)	0.6206	0.7045
	Number equal to one slightly risk averse	4	23
	Average for all other risk preferences (33 farms)	0.7554	0.8377
	Number equal to one other risk preferences	9	13
Portion of Inefficiency Attributed to RPS	Average	0.0817	0.0772
Number of Farms Impacted by Inclusion of RPS		111	108
Portion of Inefficiency Attributed to RPS if Impacted	Average	0.1943	0.1778

group remained at 0.5286 and increased from 0.6419 to 0.6987, respectively. For the slightly risk averse, one additional farm became cost efficient with the inclusion of the inverse risk preferences and six additional farms became revenue efficient. For the other risk preferences, the number of cost efficient farms increased from 3 to 9 and the number of revenue efficient farms increased from 4 to 13 with the inverse of risk preferences included. It was expected the more risk averse farms would be less efficient. The inclusion of risk preferences in the estimation further illustrated how inefficient the strongly risk averse farms really are. Risk preference is a characteristic of the producer that is difficult to change. In order to improve the efficiency of the strongly risk averse group they will have to better utilize their current input usage and outputs.

The correlations among the cost and revenue efficiency scores with and without the inverse of the risk preference scores are presented in Table 6.27. Both cost and revenue efficiency were highly correlated with their respective adjusted efficiency score. The other scores were positively correlated as well.

Table 6.27: Correlations among Efficiency Scores, 2008

	CE	CE with inverse RPS	RE	RE with inverse RPS
CE	1.0000			
CE with inverse RPS	0.8909	1.0000		
RE	0.7720	0.7037	1.0000	
RE with inverse RPS	0.7363	0.7818	0.9475	1.0000

Note: RPS is the Risk Preference Score

Figure 6.3 and Figure 6.4 provide an illustration of the impact of the inclusion of the inverse risk preference scores on cost and revenue efficiency. The yellow markers represent the farms with a strongly risk averse risk preference score. The farms represented by green markers are slightly risk averse and the purple markers indicate all other risk preferences. The green and purple markers reveal the most increases in efficiency with the consideration of the inverse risk preference scores because they are moving away from the original efficiency measure and approaching an efficiency score of one. The least movement is observed for the strongly risk averse farms. The strongly risk averse farms are clearly hindered by their risk preference.

The farms were divided into value of farm production (VFP) categories and t-tests were used to determine if there were any statistical differences between the efficiency measures of each group (Table 6.28). The smallest farms were strongly risk averse on average and the larger categories were slightly risk averse on average. The larger farms were more diversified and income was coming from more sources than the smaller farms. Efficiency scores were significantly higher for the farms with a VFP of $500,000 or more.

Figure 6.3: Cost Efficiency with and without Risk Preference Score, 2008

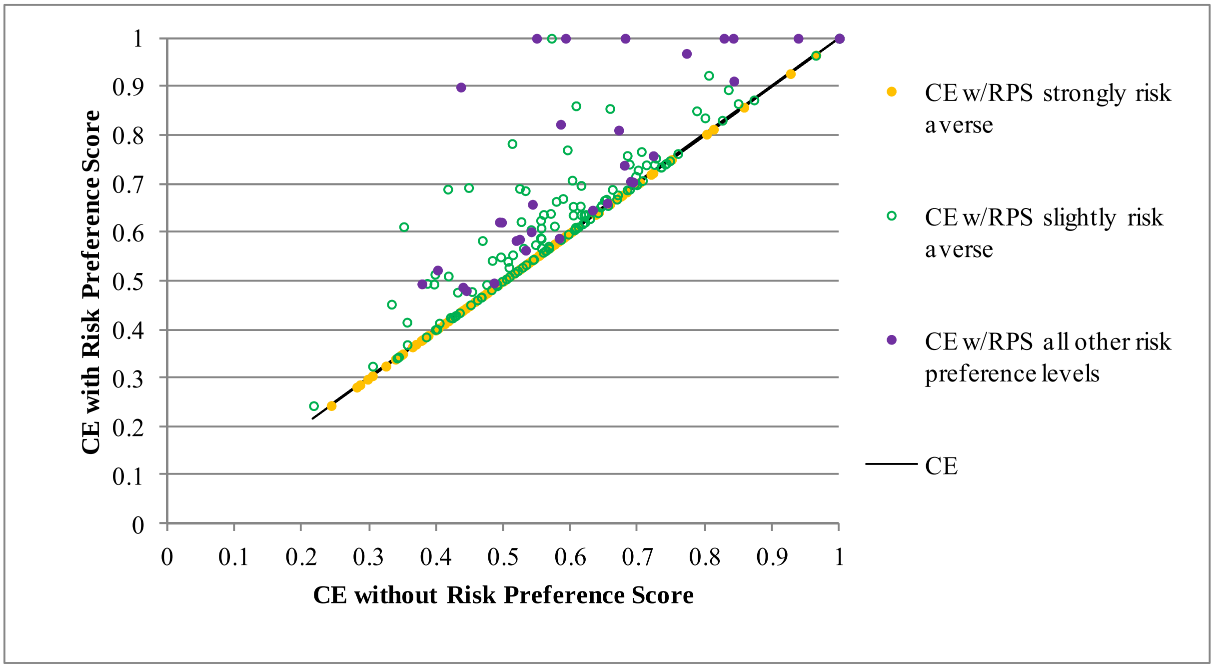


Figure 6.4: Revenue Efficiency with and without Risk Preference Score, 2008

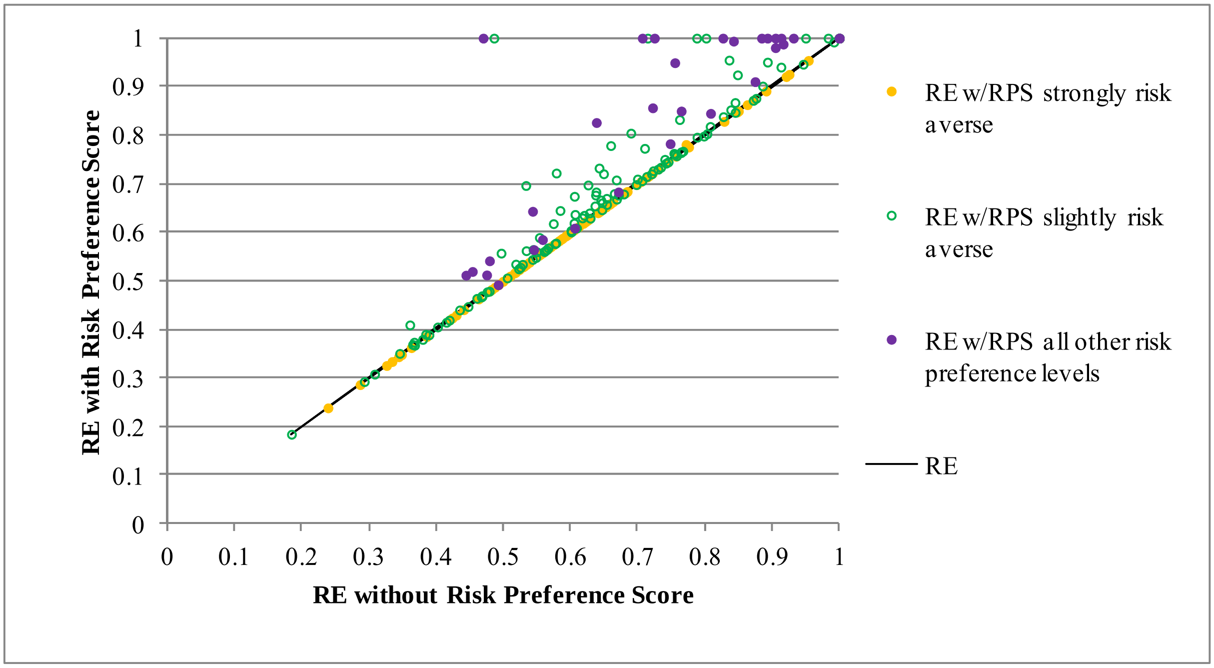


Table 6.28: Efficiency by Value of Farm Production (VFP) Category, 2008

	Less than $100,000	$100,000 to $249,999	$250,000 to $499,999	$500,000 and more
Number of Farms	34	74	81	69
Average VFP	62,307[a]	177,077[b]	374,501[c]	912,331[d]
Average RPS	19.74[a]	23.68[b]	26.57[bc]	30.25[c]
Average Inverse RPS	0.0591[a]	0.0510[a]	0.0491[a]	0.0387[b]
Diversification Index	0.5869[a]	0.4424[b]	0.3911[c]	0.3875[c]
Average Cost Efficiency	0.5006[ab]	0.5219[a]	0.5650[b]	0.6584[c]
Number of Efficient Farms	2	0	0	4
Average Cost Efficiency with RPS	0.5351[a]	0.5738[a]	0.5932[a]	0.6841[b]
Number of Efficient Farms	3	1	3	6
Average Revenue Efficiency	0.6307[a]	0.6179[a]	0.6396[a]	0.7942[b]
Number of Efficient Farms	7	9	3	12
Average Revenue Efficiency with RPS	0.6450[a]	0.6547[a]	0.6605[a]	0.8173[b]
Number of Efficient Farms	8	14	4	20

Note: Unlike superscripts indicate the means are statistically different at the 5% level.

The impact of farm size in terms of total average assets, farm type based on the percentage of time devoted to crop production, and risk preference on cost and revenue efficiencies and the difference between the efficiency scores with and without risk preference are presented in Table 6.29. Holding all else equal, an increase in assets would result in an initial decline in efficiency followed by an increase in efficiency for the measures without the risk preference score. This indicates economies of size may not be as important as often thought. However, further exploration of this area would be required as the coefficients are not all statistically significant. An increase in the time devoted to crop production has a positive and statistically significant affect on cost and revenue efficiencies without the risk preference score. The risk preference score had a positive effect on cost and revenue efficiency and cost and revenue efficiency with the risk preference score. A higher risk preference score indicates a less risk averse individual.

Table 6.29: Impact of farm size, type, and risk preference on efficiency scores and differences between efficiency scores, 2008

	CE	CE with inverse risk preference score	RE	RE with inverse risk preference score	Difference between:	CE with and without inverse risk preference score	RE with and without inverse risk preference score
Intercept	0.455513***	0.593930***	0.558855***	0.664052***		0.138417**	0.105197
	(0.041420)	(0.047734)	(0.053224)	(0.058164)		(0.064530)	(0.081290)
Assets	-0.003794	-0.000594	-0.006357**	0.002633		0.003200	0.008990**
	(0.002317)	(0.002650)	(0.002978)	(0.003254)		(0.003610)	(0.004548)
$Assets^2$	0.000092*	-0.000013	0.000172***	-0.000068		-0.000105	-0.000239***
	(0.000047)	(0.000054)	(0.000060)	(0.000066)		(0.000073)	(0.000092)
Crop Labor Percentage	0.094869**	-0.015500	0.129138**	-0.041026		-0.079369	-0.170164
	(0.045742)	(0.052715)	(0.058778)	(0.064233)		(0.071264)	(0.089772)
Risk Preference Score	0.002763***	0.000406	0.002330**	0.001847		-0.002358	-0.000483
	(0.000806)	(0.000929)	(0.001035)	(0.001131)		(0.001255)	(0.001581)
Adjusted R^2	0.0647	-0.0105	0.0649	0.0012		0.0205	0.0321

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.
Assets are equal to total assets divided by 100,000.

Table 6.30 shows the impact of the five inputs and risk preference on efficiency scores and the difference between efficiency scores. An increase in labor has a negative and statistically significant affect on efficiency scores without the risk preference score and a positive but not statistically significant affect on cost and revenue efficiency with the inverse risk preference score. The coefficient for fuel inputs was not statistically significant for any of the efficiency measures. The crop inputs have a positive effect on all the efficiency scores. The livestock inputs have a positive effect on the efficiency scores without adjusting for risk preference and a negative effect on the efficiency scores with risk preference. Capital has a positive and significant affect on revenue efficiency without risk preferences and a negative and not statistically significant affect on the other efficiency measures. The risk preference score had a positive effect on the efficiency scores indicating efficiency scores increase as risk aversion decreases.

Risk preference clearly impacts a farms' efficiency. This may be due to underlying human capital characteristics that cannot easily be quantified. As expected, the farms with a strongly risk averse manager were less efficient and likely not adopting the newest production technologies. The extent of the strongly risk averse farms relative inefficiency was even more troublesome when adjusting for their risk preference as few farms with a strongly risk averse manager experienced an improved efficiency score with risk preferences considered. The following section provides a summary and implications of this dissertation and concludes by highlighting future extensions of this research.

Table 6.30: Impact of inputs and risk preference on efficiency scores and differences between efficiency scores, 2008

	CE	CE with risk preference score	RE	RE with risk preference score	Difference between:	CE with and without risk preference score	RE with and without risk preference score
Intercept	0.514704***	0.593667***	0.619910***	0.640147***		0.0789634**	0.020238
	(0.025472)	(0.030279)	(0.033488)	(0.037014)		(0.040052)	(0.051743)
Labor	-0.039284*	0.018942	-0.049673*	0.028331		0.058227	0.078003
	(0.020116)	(0.023912)	(0.026446)	(0.029230)		(0.031630)	(0.040862)
Crop Inputs	0.006500***	0.000459	0.005849**	0.000991		-0.006041**	-0.004858
	(0.001756)	(0.002088)	(0.002309)	(0.002552)		(0.002762)	(0.003568)
Fuel	0.004743	-0.007394	-0.010912	-0.005783		-0.012137	0.005129
	(0.006375)	(0.007578)	(0.008381)	(0.009264)		(0.010024)	(0.012950)
Livestock Inputs	0.003910**	-0.001269	0.004005*	-0.001042		-0.005179**	-0.005047
	(0.001618)	(0.001924)	(0.002128)	(0.002352)		(0.002545)	(0.003287)
Capital	-0.001314	-0.000532	0.002818*	-0.001044		0.000782	-0.003862
	(0.001244)	(0.001479)	(0.001635)	(0.001808)		(0.001956)	(0.002527)
Risk Preference Score	0.001596*	0.000665	0.001020	0.002014		-0.000931	0.000994
	(0.000823)	(0.000961)	(0.001082)	(0.001196)		(0.001295)	(0.001673)
Adjusted R^2	0.1201	-0.0115	0.0791	-0.0061		0.0613	0.0245

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.
Crop Inputs, Fuel, Livestock Inputs, and Capital were all divided by 10,000.

Chapter 7 - Conclusions

7.1 Summary

This study provided a link between two important areas of economic research: efficiency and risk. Research often fails to address the necessity of considering them together. Chapter 2 provides an overview of literature on both topics as well as frontier analysis and the nonparametric approach. The motivation for this study was partly drawn from the lack of mention of risk in the efficiency analyses as well as the use of non-discretionary inputs and bad outputs to model undesirable or uncontrollable variables.

One objective of this study was to determine what portion of standard measures of inefficiency could be attributed to risk. This was addressed by first estimating standard cost- and revenue-based efficiency scores that are based on inputs and outputs that are under the operator's control. Two risk measures were calculated based on previous research related to risk (variability in outputs and downside risk) and each was included into a separate risk adjusted efficiency measure. The difference between the risk measures and the traditional input and output efficiency calculation was the inclusion of risk as a non-discretionary input or an input out of the operator's control (not a choice variable) in the programming problem.

The analysis was performed using a sample of Kansas Farm Management Association farms with continuous data available from 1993-2010. The 18 years were further reduced to 8 years to accommodate the risk measures chosen because the risk was based on the variability in outputs and the downside risk from the previous 10-year periods. Variability in outputs was defined as the standard deviation of crop output and livestock output. Downside risk was the weighted summation of net farm income below the amount needed to pay for unpaid labor. If net farm income was greater than the amount needed to pay for unpaid labor, downside risk was zero. If net farm income was less than the amount needed to pay for unpaid labor the absolute value of net farm income minus unpaid labor was used.

As expected, risk did account for a portion of the inefficiency observed in many of the farms. The average cost efficiency without risk was 0.6763 and increased to 0.7200 and 0.7018 with cost efficiency adjusted by variability and downside risk, respectively. The average revenue efficiency without risk was 0.7611 and increased to 0.8372 and 0.7811 with the revenue efficiency adjusted by variability and downside risk, respectively. For the farms impacted by the inclusion of risk, variability in outputs accounted for approximately 28.06 percent of the cost inefficiency and 42.53 percent of the revenue inefficiency on average and downside risk accounted for approximately 22.66 percent of the cost inefficiency and 30.58 percent of the revenue inefficiency. The amount of inefficiency attributable to risk was not as large as *a priori* beliefs might suggest. Risk did account for over 50 percent of the inefficiency observed for some farms, but for many farms adjusting for risk did not help to explain any inefficiencies.

Correlation coefficients were relatively large between the efficiency measures. This was as expected. Cost and revenue (economic) efficiency measures were focused on because they were deemed to be the most relevant. The efficiency scores and the efficient farms varied across the measures. It is not evident that one measure (cost or revenue) should be preferred over the other. They are clearly measuring two separate things: optimal inputs given outputs (for cost efficiency) or optimal outputs given inputs (for revenue efficiency).

The farms impacted by the risk adjusted efficiency measures were generally not the same farms and the impacts of the risk measures were different. Future research may address what risk measure is the most useful. It is likely that the risk measure used may vary based upon data availability and the objective of the study.

A separate data set of 258 Kansas Farm Management Association Farms who completed a survey used to determine a risk preference score was also analyzed (Pope 2009). This data set was strictly for 2008 corresponding to the year the survey was completed. The risk preference scores in the sample ranged from 5 to 86 where a smaller value represents stronger risk aversion. The average cost efficiency for the 258 farms was 0.5691 and increased to 0.6155 with the consideration of risk preference scores. The average revenue efficiency was 0.6735 and increased to 0.7020 with risk preference scores.

Almost all increases in efficiency and the number of efficient farms with the consideration of the farmer's risk preference were observed for the slightly risk averse and other risk preference farms. The strongly risk averse farms had no to little change in efficiency with the consideration of risk preference scores. The traditional efficiency measures were lower for the strongly risk averse farms and the smallest farms in terms of value of farm production were the most risk averse. This is consistent with previous research which has indicated risk averse producers will be more hesitant to adopt new technology and will produce less than under other risk preferences (Ben Jemaa 2007, Dillon and Anderson 1971, Robinson and Barry 1987).

7.2 Implications

Efficiency measured using data envelopment analysis overstates the inefficiency and corresponding improvement that could be made to increase efficiency when risk is not accounted for in the problem. Risk explains a portion of the inefficiency and needs to be included to obtain a more accurate efficiency score. For some farms, risk does not matter and they have more opportunities to increase efficiency through better management and utilization of resources. For other farms, risk is a major hindrance. In some instances, risk explained the entire inefficiency of the farm.

The dissertation above identified differences between the efficient farms under cost and revenue efficiencies. It is certainly plausible for a farm to be cost inefficient and revenue efficient or revenue inefficient and cost efficient. These measures are capturing two different types of farms. Traditionally, it is assumed producers are cost minimizers. As marketing becomes more important to farms the necessity of considering producers as revenue or profit maximizers will strengthen. Both cost and revenue efficiency should be calculated if the data allows to obtain a more accurate representation of the efficiency of the farms in the sample.

Further implications arise from the risk preference scores. Risk preference scores allow heterogeneity among producers something that is unique from most DEA analysis. Accounting for this heterogeneity, the efficiency of risk averse producers is lower than the efficiency of producers with other risk preferences. The inefficiency of producers with other risk preferences is partially explained by their risk preference score while it is not explained for the strongly risk averse producers. The approach taken to improve the efficiency of strongly risk averse producers should be different than that taken to improve the efficiency of producers with other risk preferences. Risk preferences are hard to influence especially in the short-run. Farms managed by strongly risk averse individuals are likely to be more inefficient, so small steps should be taken to gradually increase the efficiency. Drastic changes are unlikely to be made due to the individual's management characteristics of these farms.

7.3 Future Research

This study has led to a number of ideas for future research or expansions of this topic. First, the method to compute efficiency scores assumed static conditions, but it may be beneficial to estimate the models under dynamic situations. The farms may have what appears to be an excessive amount of inputs for their given outputs when the resources are actually intended to be used as inputs for future periods. One option to address this in the future is through window analysis.

Second, risk preference had a large impact on the efficiency scores for the slightly risk averse and risk neutral farms. This suggests that the relative inefficiency for risk averse farms increased when risk was considered. Risk aversion is really getting at a larger issue related to individual management characteristics or human capital. Future research in this area would benefit by focusing more on the knowledge and personality attributes of the individuals operating the farm and an attempt should be made to incorporate them into efficiency analysis.

Third, the data sets used in this study were based on whole-farm analyses. One alternative would be to instead focus on enterprise analysis. This may address some of the differences in human capital because the choice of enterprises on a farm is likely partially related to previous knowledge and experiences with risk and uncertainty.

Fourth, additional research could be conducted using certainty equivalent outputs rather than outputs and risk measures. This may be extremely enlightening with regards to the fact a risk preference score is already available for a sample of farms.

In conclusion, this study has provided a valuable link in the risk and efficiency literature. Two risk measures (variability in outputs and downside risk) were included in traditional efficiency analysis to determine the impact risk has on firm efficiency. A risk preference score was included in efficiency analysis to determine the impact of a producer's risk preference on efficiency. The inclusion of risk and risk preference did increase efficiency scores. The less risk averse farms experienced the largest increase in efficiency from the inclusion of their risk preference. This study has filled a major gap in the existing literature by examining efficiency with the inclusion of risk for a sample of farms. Contributions have been made by outlining a framework for including variables that impact the ultimate efficiency or a farm but are fundamentally out of the decision maker's control (e.g., risk).

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