IMPACT OF FEDERAL CROP INSURANCE ON NORTH DAKOTA AGRICULTURE PRODUCTION EFFICIENCY

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ABSTRACT

This study examines the impact of three major policy shifts in federal crop insurance on North Dakota agriculture production efficiency. An empirical application of 53 counties in North Dakota from 1980 to 2014 indicates that "with crop insurance", the technical efficiency of agriculture is higher as compared to "without crop insurance". This finding implies that producers are utilizing their input resources more effectively and are increasing the use of technology efficiently in their operations with crop insurance. The results are important to policy makers as it proves that with government support, the federal crop insurance program is not only mitigating risk for producers but also allowing producers to use resources efficiently; the program is ensuring producers will continue to lead the world as low-cost producers of food, fiber, and fuel for the American public.

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I thank my friends throughout undergraduate and graduate school for a memorable experience, which expanded my horizon beyond North Dakota, but at the same time provided a greater appreciation for my home state. I thank my previous and current colleagues in my career for time and understanding required to finish this paper. Finally, I would like to thank my family for all the love and support throughout my college career and their patients to allow me to finish this chapter of my life.

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CHAPTER 1. INTRODUCTION

Federal crop insurance has been an effective risk management tool used by producers in North Dakota and across the United States for the last two decades. In recent years, crop insurance has become the safety net of choice among farm programs for producers in North Dakota. Federal crop insurance protects the insured crop from perils which may reduce yield, including drought, wind, lightning, tornado, hail, insects, excessive moisture, and hurricanes. In addition to production risk, most plans have a price and resulting revenue component in the coverage. Therefore, today's crop insurance is a comprehensive risk management tool, which allows producers to manage the inherent risk in agriculture.

Multi-peril crop insurance has a long history in the United States beginning in 1899 when it was first introduced by a private company, The Realty Revenue Guaranty Company of Minneapolis, Minnesota. This attempt at all-risk crop insurance was not repeated the following year. In 1917, crop insurance was provided by three companies in North Dakota, South Dakota, and Montana. High indemnities were paid as the geographic pool of insured was too small to avoid drought. Revenue insurance was offered by the Hartford Fire Insurance Company in 1920. The company's indemnities exceeded premium by $1.7 million due to a decline in crop prices. Several other companies unsuccessfully attempted to provide private crop insurance.

The first federal investigation into crop insurance was led by the Republican minority leader, Senator Charles McNary of Oregon in 1922. In the same year, the United States Department of Agriculture (USDA) calculated crop losses totaling $2.6 billion from 1909 to 1918. After several years of discussion and failed government attempts to provide risk reduction tools to producers, the Agricultural Adjustment Act of 1938 in Title V provided for federal crop insurance. Within the USDA, the Federal Crop Insurance Corporation (FCIC) was created to administer the program to provide protection not only against price and income variation, but also from the great depression. Initially, the only covered crop was wheat with a coverage level of 50% or 75% of an individual farmer's average yield based on historical yield data. Premiums were based on historical data, which would have equaled indemnities if the program had been in place in previous years. The first year of crop insurance was disappointing as indemnities greatly exceeded premiums, approximately one-third of insured growers received loss payments, and the loss ratio was 1.52. Poor administration of the program and lack of data were the main reasons for the lack of success for the first year of the program.

Participation in crop insurance was voluntary and lackluster, thus to increase the participation of producers in crop insurance, new policies and amendments to policies were proposed in 1940, 1977, 1980, 1996, 2000, 2002 and 2008. The USDA created the Risk Management Agency (RMA) in 1996 to administer the public-private crop insurance program for the FCIC.

There have been three major shifts in modern crop insurance policy: Increase participation with catastrophic crop insurance (CAT) from 1980 to1993, shift from yield to revenue insurance[1] (REV) from 1994 to1999, and coverage level subsidies[2] (COV) from 2000 to 2014. These are the three shifts in crop insurance policy this research will study.

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[1] There are two general types of crop insurance: revenue-based and yield-based. Yield-based insurance products cover risk to yield loss and pay an indemnity when the yield is below the APH coverage level. Catastrophic coverage is the most basic type of yield-based insurance which covers at 50% of APH and 55% of estimated market price. Buy-up yield based coverage is available for 50-75% of yield and 55-100% of price (Shields 2010). In 2014, revenue-based policies accounted for 77% of insurance policies in which premium were paid compared to 23% for yield-based policies. An insured revenue level is calculated upon the yield history and expected market prices; an indemnity payment would be received when the actual revenue falls below the insured revenue level (Shields 2015).

[2] Coverage level subsidy rates have steadily increased since 1980 when the 65% coverage level was subsidized at 30%; in 1994, the subsidy was 41.7%; and in 2000, the subsidy was 59% (Glauber, Collins 2002). Among all policies in 2014, the average subsidy rate was 62% (Shields 2015). In 2013, North Dakota producers received approximately 10% or over $700 million of the total $7.3 billion in premium subsidies, which placed North Dakota first among states in receiving premium subsidies. Nationwide participation in the federal crop insurance program totaled 294 million acres

The CAT policy shift began with The Federal Crop Insurance Improvement Act of 1980. Crop insurance prior to 1980 mainly provided protection again catastrophic coverage for producers. In the CAT policy shift, there was an emphasis on increasing participation by increasing subsides for crop insurance premiums, and introducing optional, basic, and enterprise unit policies that would provide protection at a disaggregate level. In addition, the public-private partnership was established in which the private insurance companies would sell and service federal crop insurance to the producer (Kramer 1983).

The REV policy shift began with The Federal Crop Insurance Reform Act of 1994 and was the first meaningful change to crop insurance since 1980. Policy makers preferred crop insurance as an *ex ante* disaster program versus an *ex post* disaster assistance. Catastrophic risk protection covered 50% of the actual production history (APH) and 60% of the commodity price was provided without a premium to the farmer. In addition, subsides were increased for crop insurance buy-up policies, which provided coverage levels greater than 50% (Glauber 2004). These changes were intended to increase crop insurance participation rates, which had remained below 25% prior to 1990, but reached 40% in 1990 and 1991 (Coble, Knight, Pope, Williams 1996). Producers continued to rely on *ex post* disaster relief for risk management, due to their low participation rate in crop insurance. Beginning in 1993 and expanded by the 1994 legislation, additional crop insurance products were made available. Revenue coverage was introduced in 1997.

The COV policy shift began with The Agricultural Risk Protection Act of 2000. Crop insurance was enhanced and modified which encouraged further participation by continuing

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in 2014. Subsidy increases have been key to increasing enrollment in the crop insurance program allowing it to be a viable risk management tool for producers while reducing the need for additional disaster assistance.

to increase subsidy levels for buy-up levels of coverage. Additional crop insurance products were made available along with the higher premium subsidy levels providing producers multiple options to insure their crops (Glauber, Collins 2002).

The emphasis of crop insurance participation, types of crop insurance policies (yield versus revenue), and coverage level subsidies on the effectiveness as a risk management tool has been the primary focus of policy makers and producers. Further, most of the earlier and current crop insurance studies focused on the micro-level issues associated with crop insurance demand, premium rate, and asymmetric information due to adverse selection and moral hazard issues. Minimal and inadequate research exists to explain the overall general effect crop insurance has on agriculture production.

The outcome of this study will provide information to individual producers to reflect upon the efficiency of their operation and utilization of resources to maximize agriculture production. The implications of changes in the crop insurance policies over time will provide information for policy makers with respect to types of crop insurance, coverage levels and subsidies. United States taxpayers will appreciate the research, as they subsidize nearly 70% of crop insurance premiums.

Traditionally, producers measure success by production, cost, profit, and operate to maximize production or reduce cost. However, those measures do not show if the farm is operating on its theoretical production frontier. If the farm is operating on the theoretical production frontier, the farm will be 100% efficient and maximizing the use of input resources.

It is assumed with the availability of crop insurance, there is reduced risk to production; however, it is unknown if producers have increased or decreased their production efficiency in utilizing a fixed set of input resources. The concept of production efficiency was introduced by

Farrell (1957) and is defined as the distance of the observation from the production frontier and measured by the observed output to realized output, i.e., output that could be produced if the farm was 100% efficient from a given set of inputs. Given, the public-private nature of crop insurance, did net crop insurance (NCI) increase or decrease producers' production efficiency? If NCI increased producers' efficiency, the program not only protects producers at the time of risk, but also enabled the producers to efficiently utilize input resources. Alternatively, if NCI decreased producers' efficiency, the program may be protecting producers at the time risk, while creating inefficiencies in the utilization of input resources. This research aims to discover if NCI is increasing or decreasing producer efficiency.

In this research, a heteroscedasticity stochastic frontier production function model is used to examine the importance of Federal Crop Insurance on the production efficiency of North Dakota Agriculture. The stochastic frontier production function not only evaluates the importance of input resource, but also estimates the efficiency of the firm (in our case, the individual counties). The results are presented based on an empirical application to the North Dakota agriculture county data from 1980 to 2014. The outcome of this research will provide the production efficiency of the 53 counties in the state of North Dakota for the three shifts in crop insurance policy; and estimate the importance of net crop insurance (NCI) on production efficiency. NCI is defined as the difference between potential indemnities, producer premiums and federal government premium subsidies.

The three objectives of this study include

1. Estimate the agriculture production efficiency of North Dakota by county.
2. Evaluate the importance of NCI on agriculture production efficiency by county in North Dakota.

3. Evaluate the importance of shifts in crop insurance policies on agriculture production efficiency of North Dakota Counties.

The primary objective utilizes a stochastic frontier production function[3] is to estimate the importance of input resource in producing agriculture output in North Dakota. The second objective evaluates the importance of NCI on agriculture production efficiency using a heteroskedastic stochastic frontier production function. Finally, the third objective is to evaluate the importance of crop insurance on agriculture production efficiency with an emphasis on three major shifts in crop insurance policies.

Given the lack of historical farm level crop insurance, input and output production data, this analysis used historical county level data to address these issues.

This research is organized as follows: the second chapter is the literature review, the theoretical model to jointly estimate the technical efficiency measure and primal production function is presented in chapter three. The fourth chapter presents the data and construction of the variables used in the analysis. The empirical application and results are presented in the fifth chapter followed by conclusions in chapter six.

[3] The stochastic frontier model, introduced by Aigner, Lovell, Schmidt; Meeusen, van den Broeck; and Battesse and Cora in 1977 decomposes the error term, ε into random error, v and u inefficiency. Stochastic frontier analysis has become a popular tool to model the production relationship between input and output quantities and has been primarily used to estimate the technical efficiency of firm. Since it was introduced in 1977, the stochastic frontier analysis has been evolving theoretically with surge in empirical application. In 1982, Jondrow, Materov, Lovell, and Schmidt suggested a method to estimate firm specific inefficiency measures. Furthermore, progress has been made on extending to fixed effects, random effects and random parameters panel models, time invariant and time variant models, correcting for heteroskedasticity and heterogeneity and alternative distributions (normal- half normal, normal-exponential and normal-gamma) of u technical efficiency term. Additionally, research has investigated the influence of a broader set of determinants of technical efficiency, namely geographic variables, market structure conduct and performance hypothesis, policy variables and size of the firm.

CHAPTER 2. LITERATURE REVIEW

Federal crop insurance began in 1938 as a fully government operated insurance program protection against yield loss without premium subsidies. Since 1980, the program has evolved into partnership between the federal government and private insurance companies with an array of insurance products including yield and revenue protection with substantial premium subsidies. Crop insurance has become a great risk management tool for producers; however, the government policy struggle continues over the appropriate role of government. New weather or area-yield based policies may provide alternative options (Barnett 2000).

The federal government and policy-makers continually struggle with how to successfully manage risk in agriculture and reduce government outlays. A major effort behind the Federal Crop Insurance Act of 1980 was to subsidize crop insurance, thus eliminating disaster programs. Such a policy direction, in theory, would expand risk management coverage and reduce government costs. Adoption and participation in crop insurance was slow and in 2001 reached 210 million acres from 26 million acres in 1980. From 1980 to 2000, outlays for disaster programs continued and totaled $15 billion, but crop insurance indemnities totaled $22 billion. Crop insurance has thus far failed to fully replace disaster programs (Glauber and Collins 2002).

Expected utility maximization is not realized when producers choose their crop insurance coverage level. Babcock (2015) applied cumulative prospect theory to crop insurance choices by framing it as an individual investment. A loss occurs if the premium paid is higher than the indemnity received.

Goodwin, Vandeveer, and Deal (2004) investigated the effect crop insurance has on acreage of corn and soybeans in the Corn Belt and wheat and barley in the Upper Great Plains. Results indicated that higher crop insurance participation rates resulted in statistically significant, but minimal acreage shifts. Crop insurance premium subsides of 30% increased acres from 0.2% to 1.1%.

Hennessy, Babcock, and Hayes (1997) compared crop revenue insurance to the efficiency of the 1990 farm program. Revenue insurance only provides subsides when revenue is low, marginal utility is high, and that revenue is most important. Revenue insurance at the 75% level would provide the same protection as the 1990 farm program with a 75% decrease in cost.

Coble, Knight, Pope, and Williams (1996) investigated farm-level crop insurance demand with panel data for Kansas wheat farms utilizing a random-effects, binomial probit model. The price elasticity of demand was found to be inelastic at -0.65. Adverse selection was not supported as pre-season weather variables were not significant.

Goodwin and Vado (2007) investigated the justification for government involvement in crop insurance and farm disaster programs. A panel VAR analysis was conducted between market returns and the three type of farm program payments: crop insurance, disaster assistance, and direct payments. An interesting result is that crop insurance and disaster assistance imply higher levels of market income risk. This result is consistent with the thought that increased risk in agriculture is attributed to subsidized crop insurance and disaster assistance. Private insurance may be able to provide viable coverage, but would be smaller and more specialized.

O'Donoghue, Roberts, and Key (2008) investigated how the 1994 Federal Crop Insurance Reform Act with increased subsidies altered the level of diversification of United States farms. Farm-specific changes were tracked over time and the relationship between average returns and farm diversification were estimated. Farm specialization increased modestly and as did production efficiency; however, the efficiency gains were significantly less than the crop insurance subsidies.

Reinsurance is required by private crop insurance markets as weather risk has a high correlation to farm-level yields; this defeats attempts at pooling risks across farms. Miranda and Glauber (1997) find that crop insurance is 20 to 50 times riskier than if farm yields were stochastically independent. Area yield reinsurance policies would allow for coverage of systemic crop loss risk, resulting in risk exposure experience by conventional property liability insurance companies.

In the frontier production function, Aigner, Lovell, and Schmidt (1977) define the disturbance term as the sum of symmetric normal and (negative) half-normal random variables. Tests of the model had small one-sided disturbance, indicating high levels of efficiency relative to a stochastic frontier.

Shaik (2015) investigated the importance of short- and long-run liquidity or debt risk on technical inefficiency and productivity. An alternative panel estimator of normal-gamma stochastic frontier model is applied using a simulated maximum likelihood estimation technique. Results indicate a difference in the parameter coefficients of gamma stochastic production function, and heterogeneity function variables between the pooled and the Swamy–Arora panel models. Variance in efficiency and productivity is explained by the short-run and long-run risk or variations in liquidity or debt-servicing ratio.

CHAPTER 3. ECONOMIC FRAMEWORK

A primal production theory assumes a relationship between non-allocable exogenous input vector $(\mathbf{x})$ in logs and technology used in the production of an endogenous aggregate output (y) in logs. The empirical production function with error (ε) is represented as:

$$y = f(\mathbf{x};\boldsymbol{\beta}) + \varepsilon \ . \tag{1}$$

The primal production function is estimated using stochastic frontier analysis (SFA) that decomposes the traditional error (ε) into a symmetrical random error (v) and a one-sided error or inefficiency (u). SFA was introduced in 1977 by Aigner Lovell and Schmidt (normal-half normal and an exponential distribution), Meeusen and van den Brubeck (exponential distribution), and Bates and Corra, that decomposes the error term, ò into a symmetrical random error, (v) and a one-sided error or inefficiency (u).

The stochastic frontier model for primal production function is represented as:

$$y = f(\mathbf{x};\boldsymbol{\beta}) + v - u \tag{2}$$

where (y) represents an endogenous dependent variable in logs, (x) is a vector of exogenous independent inputs in logs and deterministic time trend used in the production function; $\boldsymbol{\beta}$ is a vector of coefficients associated with inputs.

Since its introduction in 1977, SFA has been evolving theoretically with a surge in empirical application. The last decade saw the introduction of fixed-effects and random parameters SFA panel models and time invariant and time variant models. These advancements corrected for heteroskedasticity/heterogeneity and alternative distributions (half normal, exponential, or truncated normal distribution) of technical efficiency term (u). Additionally, research has investigated the influence of a broader set of determinants of technical efficiency namely geographic variables, market structure conduct and performance hypothesis, policy variables and size of the firm on inefficiency.

Equation (2) can be extended by introducing heterogeneity in the one-sided inefficiency (u) to evaluate the importance of crop insurance on the performance (efficiency) of agriculture production. The extended model is defined as:

$$\begin{aligned} y &= f(\mathbf{x};\boldsymbol{\beta}) + v - u \\ \sigma_{\mathrm{u}}^{2} &= \exp(\delta' \mathrm{z}) \end{aligned} \tag{3}$$

where (σ_{u}^{2}) is the variance of inefficiency and modelled as a function of risk or variance in (z) variables including short-run and long-run NCI. The inefficiency variances in equation (3) can be paraphrased as variance in inefficiency and defined as:

$$\begin{aligned} y &= f(\mathbf{x};\boldsymbol{\beta}) + v - u && \textit{Output} \\ \sigma_{\mathrm{u}}^{2} &= \exp(\delta' \mathrm{z}) && \textit{Inefficiency}\,. \end{aligned} \tag{4}$$

In this research, the random effect[4] (tre) panel stochastic frontier production function is represented as:

$$y_{it} = f\left((\alpha + w_i), \mathbf{x};\boldsymbol{\beta}\right) + v_{it} - u_{it} \tag{5}$$

where w_i is time invariant firm specific random term.

The main difference between the panel random and panel fixed model is the additional assumption that w_i and all other variables are uncorrelated. Combining equation (4) and (5) gives the following:

[4] Alternatively, the fixed effect (tfe) panel stochastic frontier model can also be used. The fixed effect model is represented as $y_{it} = f(\alpha_i, \mathbf{x};\boldsymbol{\beta}) + v_{it} - u_{it}$, where α_i is the cross-section (or county) specific constant.

$$y_{it} = f\left(\left(\alpha + w_i\right), \mathbf{x}; \boldsymbol{\beta}\right) + v_{it} - u_{it}$$
$$\sigma^2_{\text{inefficiency}} = \exp\left(\delta' \mathrm{z}\right) \tag{6}$$

Equation (6) will be used in the estimation of a) input elasticities of production function, b) evaluate the importance of NCI (short-run and long-run variance) on technical efficiency variance, and c) change in the impact of NCI across the three major shifts in crop insurance policy.

CHAPTER 4. DATA SOURCES AND CONSTRUCTION OF THE VARIABLE[5]

The USDA's Economic Research Service constructs and publishes the state and aggregate production accounts for the farm sector. The United States Department of Commerce's Bureau of Economic Analysis publishes county level production accounts for the farm sector including revenue of outputs and cost of input resources. To estimate the primal production function, theory suggests the use of output and input quantities. The log difference in output, $d \ln IOQ$ is computed as:

$$d \ln IOQ = d \ln Revenue - d \ln OPI \tag{7}$$

where the logarithmic change in output price index is $d \ln OPI$ and the logarithmic change in revenue is $d \ln Revenue$. The implicit output quantity index (IOQ) is computed using $d \ln IOQ$ and choosing first year as 100. The log difference in output, $d \ln IOQ$ is computed as:

$$d \ln IIQ = d \ln Cost - d \ln IPI \tag{8}$$

where the logarithmic change in input price index $d \ln IPI$ and the logarithmic change in cost is $d \ln Cost$. The implicit input quantity index (IIQ) is computed as using $d \ln IIQ$ and choosing first year as 100.

The input price index and output price index used in the analysis are unique, as the national price indices are used to compute individual county price indexes. For example, assume a county produces crops and livestock. To develop county specific price index, the share of crop revenue and livestock revenue are used to weight the national crop price index and national livestock price index, respectively. The county specific input price index (IPI) is computed as:

[5] This is taken from Shaik, 2013 and 2015.

$$IPI = \left\{ \begin{array}{l} \left(\sqrt{rs_t^C * rs_{t-1}^C}\right) \ln\left(\frac{CPI_t}{CPI_{t-1}}\right) + \\ \left(\sqrt{rs_t^L * rs_{t-1}^L}\right) \ln\left(\frac{LPI_t}{LPI_{t-1}}\right) \end{array} \right\} \quad (9)$$

where CPI and LPI are the national crop price index and livestock price index; rs^C and rs^L are the revenue shares of crops and livestock.

The price index approach uses the ratio between the weighted growth rate of crop and the weighted growth rate of livestock, as a measure of price gain between any two points in time. An index of price is computed by choosing first year as 100; a similar approach is used in the computation of four input price indexes. The county specific input price indexes for the four inputs also were developed in a similar fashion by using county specific input cost share weights. The county specific input and output price indexes were used in the computation of implicit input quantity index (IIQ) and implicit output quantity index (IOQ), respectively.

An aggregate implicit output quantity index and four implicit input quantity index variables (capital, labor, farm inputs, and manufactured inputs) are used in the estimation. An aggregate agriculture implicit output quantity (IOQ) index is computed from output cash receipts and a county specific output price index defined in equation (7). Equation (8) is used in the computation of implicit capital, labor, farm input and manufacture input quantity indexes.

The capital quantity index is computed from the sum of repair and operation cost of machinery; depreciation, interest, rent, and taxes; and other miscellaneous expenses; and county specific capital price index. The labor quantity index is computed from the sum of hired workers' cash pay and perquisites, employers' contributions for social security and Medicare, and payments for contract labor, machine hire, and custom work; and county specific labor price index. The implicit quantity index of farm input is computed from the sum of feed, livestock, and seed purchases; and county specific farm input price index. Finally, the implicit quantity index of manufactured input is computed from the sum of fertilizer and lime, and petroleum products; and county specific manufactured input price index. Figure 1 shows the average use of input resources by North Dakota counties to producer agriculture output.

With the introduction of crop insurance in the primal production framework, the three major components of crop insurance – producer premium, premium subsidy, and potential indemnity are combined to create NCI. The crop insurance premium, indemnity and subsidy data were collected for all the crop insurance policies and aggregated by county and year from 1980 to 2014. Since crop insurance is output based, output crop price index along with NCI are used in the computation of implicit NCI quantity index that is consistent with primal production theory framework.

CHAPTER 5. EMPIRICAL APPLICATION AND RESULTS

The three objectives are evaluated by estimating equation (5) and (6) utilizing the output and input implicit quantity index. The true random effects panel SFA regression results of equations (5) and (6) are presented in Table 2 and Table 3, respectively. Table 4 presents the summary statistics of North Dakota technical efficiency measures estimated by equation (5) and (6) by three crop insurance shifts: CAT, REV, and COV. To illustrate the changes in technical efficiency over the crop insurance shifts, Figure 2 presents the average technical efficiency measures corresponding to the three crop insurance shifts. Table 1 presents the summary statistics of variable used in the regression analysis from 1980 to 2014. Figure 1 presents the implicit input quantity indexes for each county.

A Cobb-Douglas[6] functional form for the panel stochastic frontier models with heterogeneity in the one-sided inefficiency (u) is specified. The short-run and long-run variance of NCI is specified in the inefficiency heteroskedasticity variance function. The short-run NCI variance is measured as the rolling variance for the last 5 years. The long-run NCI variance is measured as the rolling variance for the past 10 years. The Cobb-Douglas functional form with heteroskedasticity is specified as:

$$\begin{aligned} Output_{it} &= \beta_0 + \beta_1 Capital_{it} + \beta_2 Land_{it} + \beta_3 Labor_{it} + \beta_4 Chemicals_{it} \\ &\quad + \beta_5 Energy_{it} + \beta_6 Materials_{it} + \beta_7 Year + \varepsilon_{it} \\ \sigma_u^2 &= \gamma_{0,u} + \gamma_{1,u} nci_{it} + \gamma_{2,u} nciSR_{it} + \gamma_{3,u} nciLR_{it} \end{aligned} \quad (10)$$

[6] A more flexible functional form, the Translog production function is also estimated. However, the input elasticities was not in the normal range with and without imposing the properties of production function including curvature conditions. Apart from these out of range results and the focus of the paper is to illustrate the importance of short- run and long-run variability in net crop insurance on efficiency.

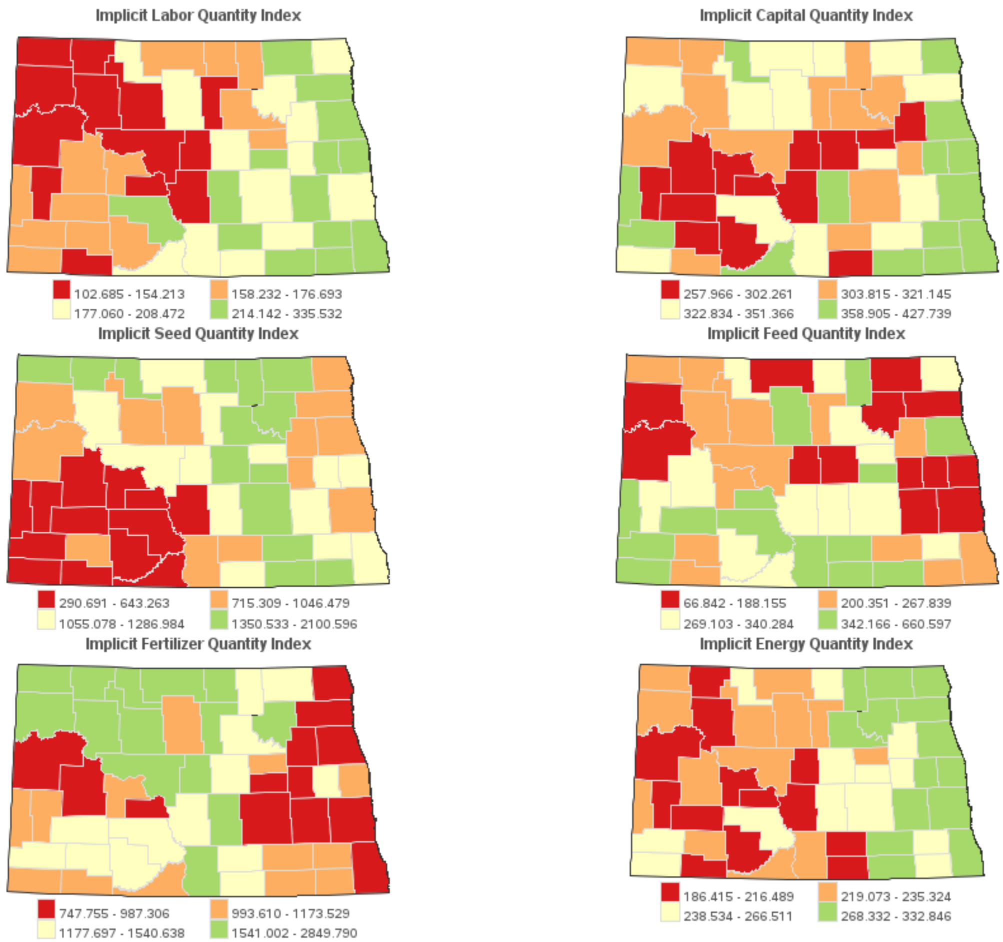

Figure 1. *State maps of implicit input quantity indexes by county*

In the primal production function in Table 3, all inputs are significant at the 5% level except for seed, average precipitation, and variance precipitation. Based on the coefficient or elasticity, a 10% increase in capital, labor, seed, feed, fertilizer, and energy input is expected to increase output production by 1.702%, 1.109%, 0.139%, 0.639%, 0.487%, and 2.249%, respectively. The trend is a proxy for technology and is positivity related to agriculture output. The average and variance of temperature variables according to the model have a negative and statistically significant effect on agricultural output. This result suggests an increase in the average or variance of the temperature would decrease agriculture production. Average of precipitation has a positive effect on output and variance of precipitation has a negative effect on agriculture output; both inputs are not significant at the 5% level.

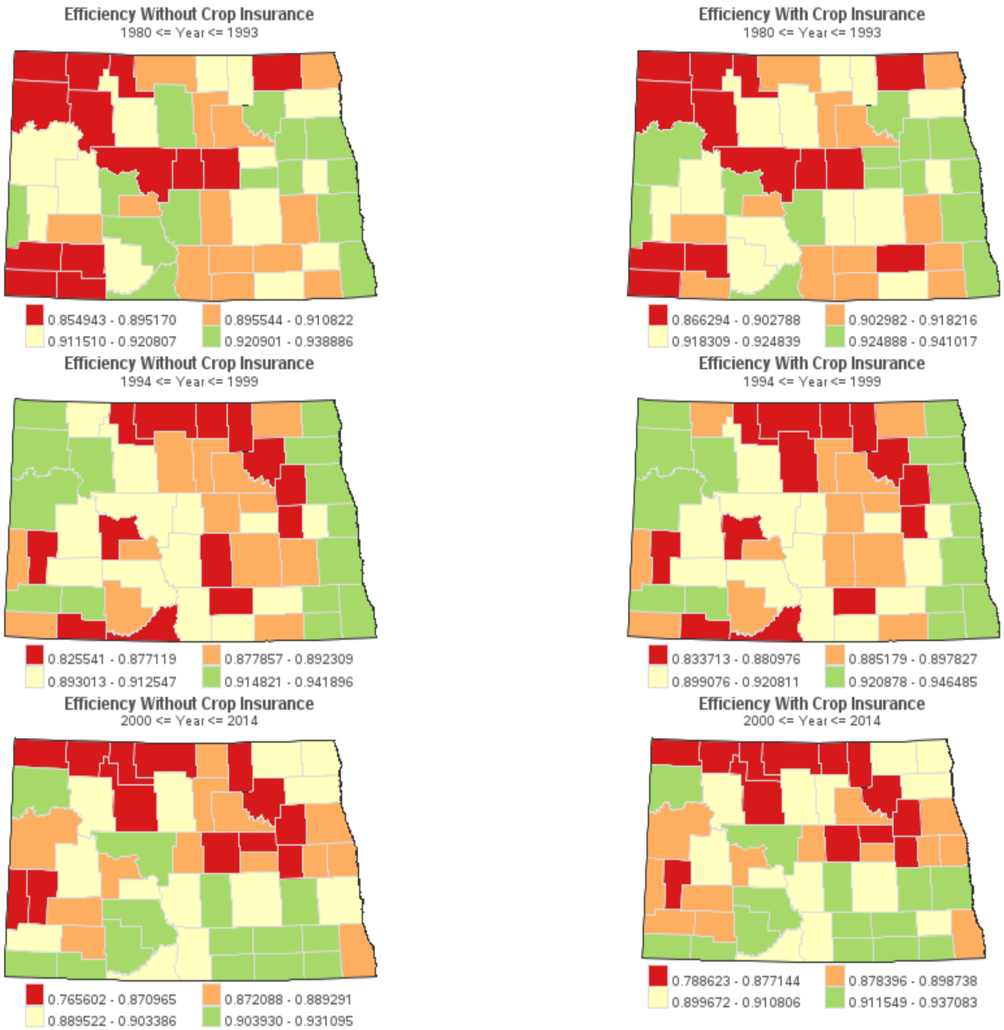

Figure 2. *State maps of efficiency without crop insurance and with crop insurance by county*

In the technical efficiency equation of the heteroskedastic stochastic frontier production function of Table 3, NCI is positive for all three time periods; however, only the variation in REV and COV are significant at the 5% level. These results indicate that NCI increases variability in technical efficiency. In the short-run risk model, NCI has the following effects:

- CAT variation is positive, however insignificant,
- REV variation is negative and insignificant, and
- COV variation is positive and significant at the 5% level.

These results suggest that in the short run NCI has increased variability technical efficiency over COV. The long-run risk variation of crop insurance is negative across all three time periods; however, only significant at the 5% level over COV. The results also suggest that in the long-run NCI reduces variability in efficiency over COV. This is key, as producers are purchasing crop insurance to reduce their risk, which also will reduce their efficiency variability to maximize resources. It is encouraging that these results were during the COV period, the most recent and reflective of current crop insurance policy.

The state level technical efficiency measures by crop insurance period in Table 4 presents an increase in technical efficiency with NCI when compared to without NCI. For CAT, technical efficiency increased from 90.51% to 91.2% with NCI. For REV, technical efficiency increased from 89.43% to 90.08% with NCI. For COV, technical efficiency increased from 88.52% to 89.35% with NCI. For each period, the technical efficiency is higher for NCI than without NCI indicating that on a statewide basis, agriculture production has taken advantage of crop insurance along with technology changes. Figure 3 illustrates the state mean technical efficiency with NCI and without NCI by major insurance shift. These results are encouraging for producers, indicating that crop insurance has increased the efficiency of producers, allowing them to increase their utilization of input resources. This implies that the federal crop insurance program is working, as it allows producers to be better stewards of their resources. As North Dakota is the leading recipient of federal crop insurance premium subsidies, these results are not surprising.

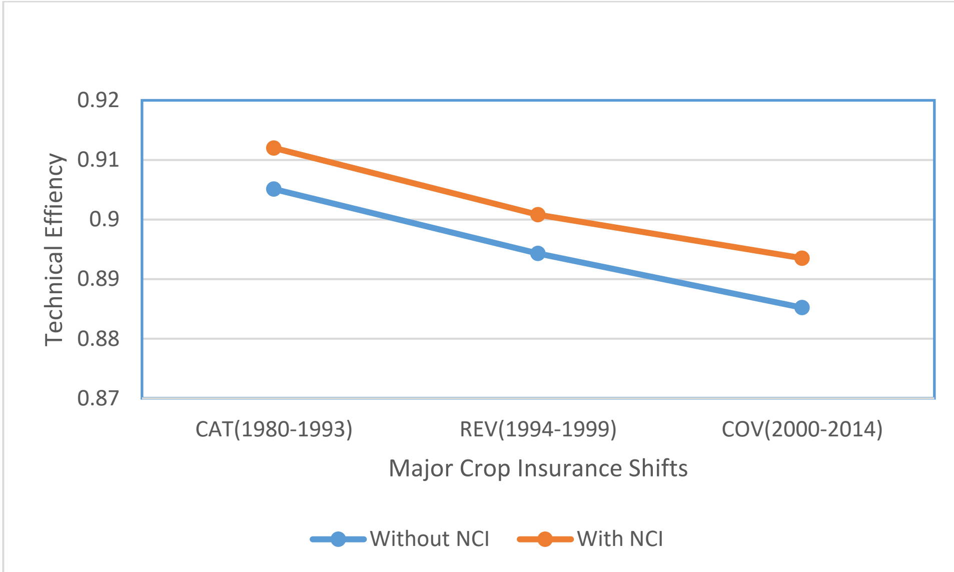

Figure 3. *State mean technical efficiency with NCI and without NCI by major crop insurance shifts*

Table 5 presents county level technical efficiency with NCI by the three crop insurance shifts and the mean technical efficiency from 1980-2014. The state mean technical efficiency of each shift has successively decreased. This decreasing trend may be attributed to land utilization including the expansion of crops in non-traditional growing areas, such as corn production further north and west in North Dakota, and farming of marginal land, which had been pasture. This decreasing trend suggests that NCI is already built into the production function, and that agriculture efficiency is declining overtime. This trend may be an indication of farm size and reduced efficiency due to transport time and farms covering large geographical areas, as farm size continues to increase in the state. Farm equipment is often under-utilized, reducing efficiency due to the significant investment; however due to narrow planting and harvest windows, the capacity is required to prevent losses.

CHAPTER 6. CONCLUSION

Federal crop insurance was introduced in 1938 and over 70 years, has become the key risk management tool for producers across the United States replacing ad hoc disaster assistance programs. The shift to crop insurance took a significant step in 1980 when the federal government began subsidizing crop insurance policy premiums and created a private-public partnership between the federal government and the private insurance companies to sell and administer crop insurance policies. Participation in the program remained low until 1994 when premium subsidies were increased and crop insurance was required to receive additional disaster assistance for a few years. In 2000, premium subsides increased again and additional revenue insurance policies became available. Today, crop insurance is the risk management tool of agriculture with 294 million acres insured across the U.S. in 2014 (Shields 2015).

The effort of this research was to estimate the production efficiency of the 53 counties in the state of North Dakota and estimate the importance of net crop insurance (NCI) on production efficiency. The primal production function is estimated with stochastic frontier analysis, which also is used to evaluate the importance of NCI on production efficiency.

The statewide mean of the technical efficiency is higher with NCI than without NCI. This data suggests that crop insurance allows producers to be more efficient, utilize their input resources more effectively, and are increasing the use of technology. Over the long-run, variation in technical efficiency is reduced with NCI implying crop insurance has long-term positive effects to producers' resource utilization, as lower variability results in lower risk. However from 1980 to 2014, the mean state technical efficiency with crop insurance has decreased, indicating crop insurance is built into the production function. Comparisons across individual counties reveal a more accurate representation, as there may have been significant changes in the use of inputs and outputs (crops) across individual counties.

The federal crop insurance program has become the program that policy makers have been attempting to achieve for decades, as it has high participation, provides high levels of risk reduction to producers eliminating the need for ad hoc disaster relief, and provides security to agricultural lenders. In addition, this research implies that federal crop insurance increases the efficiency of North Dakota producers allowing them to utilize their input resources more effectively to be low cost producers of agricultural products for the American public.

A drawback of this study is the use of county data. Further research utilizing individual farm level data may provide insight into how efficiency is affected by farm size and location, specific crops, and other variables. Investigation of the technical efficiency gains from the portion of crop insurance premiums paid by the producer and from the federal subsidy would show the level of benefit producers are receiving by the subsidization of the crop insurance policies.

Table 1. *Summary statistics of variables used in the regression analysis: 1980-2014*

Variable	N	Mean	Std Dev	Minimum	Maximum
Year	1855	1,997.000	10.102	1,980.000	2,014.000
Output	1855	518.814	184.912	203.874	1,437.380
Labor	1855	186.706	65.679	26.851	474.015
Capital	1855	330.341	88.839	129.886	762.702
Seed	1855	1,041.240	765.189	100.820	4,851.290
Feed	1855	278.470	171.148	17.085	1,902.390
Fertilizer	1855	1,305.850	699.668	108.189	5,330.150
Energy	1855	244.859	58.761	39.291	516.140
NCI	1855	245,149	927,773	0	18,107,040
NCI_Short Run Risk	1855	208,431,085,576	1,732,110,400,000	0	34,752,296
NCI_Long Run Risk	1855	138,031,677,190	941,865,645,877	0	18,159,297
Average Temp	1855	5.438	1.553	0.433	10.667
Variance Temp	1855	142.664	29.217	57.597	245.562
Average Precp	1855	29.487	15.181	5.569	131.130
Variance Precp	1855	816.526	1,226.610	11.771	18,250.610

The short-run and long-run risk are defined as the second moment, i.e., variance of actual net crop insurance. Hence the values are very big. This will lead to very low parameter coefficient.

Table 2. *Panel true random effects SFA results of production function*

	Coef.	Std. Err.	z	P>z	[95% Conf.Interval]	
			Primal Production Function			
Capital	0.1551	0.0137	11.32	<0.0005	0.1283	0.1820
Labor	0.0943	0.0171	5.52	<0.0005	0.0608	0.1278
Seed	0.0257	0.0151	1.71	0.088	-0.0038	0.0553
Feed	0.0483	0.0093	5.19	<0.0005	0.0301	0.0665
Fertilizer	0.0293	0.0143	2.05	0.04	0.0013	0.0573
Energy	0.1932	0.0209	9.26	<0.0005	0.1523	0.2341
Trend	0.0267	0.0008	31.52	<0.0005	0.0251	0.0284
Average Temp	-0.0220	0.0035	-6.26	<0.0005	-0.0288	-0.0151
Variance Temp	-0.0008	0.0002	-5.14	<0.0005	-0.0012	-0.0005
Average Precp	-0.0002	0.0003	-0.52	0.601	-0.0008	0.0005
Variance Precp	0.0000	0.0000	0.97	0.331	0.0000	0.0000

Table 3. *Panel true random effects SFA results of production function with heteroskedasticity (efficiency variance)*

	Coef.	Std. Err.	z	P>z
	Primal Production Function			
Capital	0.1702	0.0164	10.4	0
Labor	0.1109	0.0202	5.48	0
Seed	0.0139	0.0177	0.79	0.432
Feed	0.0639	0.0106	6.04	0
Fertilizer	0.0487	0.0163	3	0.003
Energy	0.2249	0.0246	9.13	0
Trend	0.0228	0.0010	23.34	0
Average Temp	-0.0240	0.0040	-5.99	0
Variance Temp	-0.0010	0.0002	-5.38	0
Average Precp	0.0000236	0.0004	0.06	0.951
Variance Precp	-0.0000001	0.0000	-0.03	0.978
	Production Technical Efficiency Function			
	NCI			
CAT (1980-93)	0.000001690000	0.000000896000	1.88	0.059
REV (1994-99)	0.000000924000	0.000000326000	2.84	0.005
COV (2000-14)	0.000000340000	0.000000128000	2.65	0.008
	NCI_Short Run Risk			
CAT (1980-93)	0.000000000119	0.000000000064	1.86	0.063
REV (1994-99)	-0.000000000001	0.000000000005	-0.27	0.785
COV (2000-14)	0.000000000001	0.000000000000	2.51	0.012
	NCI_Long Run Risk			
CAT (1980-93)	-0.000000000299	0.000000000156	-1.92	0.055
REV (1994-99)	-0.000000000008	0.000000000007	-1.15	0.25
COV (2000-14)	-0.000000000002	0.000000000001	-2.54	0.011
Intercept	-4.5175	0.1203	-37.55	0

The short-run and long-run risk are defined as the second moment, i.e., variance of actual net crop insurance. Hence the values are very big. This will lead to very low parameter coefficient.

Table 4. *Summary statistics of technical efficiency estimated from true random effects SFA by major crop insurance shifts: 1980-2014*

Variable	Mean	Std Dev	Minimum	Maximum
		Without NCI		
		CAT (1980-1993)		
Inefficiency	0.1018	0.0662	0.0240	0.5841
Efficiency	0.9051	0.0555	0.5576	0.9762
		REV (1994-1999)		
Inefficiency	0.1156	0.0939	0.0283	1.000
Efficiency	0.8943	0.0695	0.3460	0.9721
		COV (2000-2014)		
Inefficiency	0.1274	0.1093	0.0234	0.9396
Efficiency	0.8852	0.0852	0.3908	0.9769
		With NCI		
		CAT (1980-1993)		
Inefficiency	0.0939	0.0609	0.0159	0.5466
Efficiency	0.9120	0.0515	0.5789	0.9842
		REV (1994-1999)		
Inefficiency	0.1082	0.0926	0.0285	1.0000
Efficiency	0.9008	0.0684	0.3591	0.9719
		COV (2000-2014)		
Inefficiency	0.1174	0.1020	0.0201	0.8973
Efficiency	0.8935	0.0803	0.4077	0.9801

Due to the distributional assumptions and estimation, some of efficiency measures were higher than 1 at the second decimal and rounded to the first decimal.

Table 5. *County level technical efficiency with NCI by major crop insurance shift: 1980-2014*

County	CAT (1980-93)	REV (1994-99)	COV (2000-14)	Mean (1980-2014)
Adams, ND	0.9030	0.8761	0.9236	0.9072
Barnes, ND	0.9097	0.8991	0.9163	0.9107
Benson, ND	0.9116	0.8910	0.8869	0.8975
Billings, ND	0.9229	0.8810	0.7886	0.8582
Bottineau, ND	0.9138	0.8337	0.8521	0.8736
Bowman, ND	0.8750	0.8940	0.9371	0.9048
Burke, ND	0.8705	0.8975	0.8735	0.8764
Burleigh, ND	0.9249	0.9148	0.9057	0.9143
Cass, ND	0.9286	0.9465	0.9218	0.9259
Cavalier, ND	0.8767	0.8917	0.9003	0.8894
Dickey, ND	0.9198	0.8974	0.9192	0.9157
Divide, ND	0.8663	0.9358	0.8507	0.8715
Dunn, ND	0.9235	0.9033	0.9068	0.9129
Eddy, ND	0.9250	0.8935	0.8725	0.8971
Emmons, ND	0.9043	0.9208	0.9059	0.9080
Foster, ND	0.9324	0.9030	0.8905	0.9094
Golden Valley, ND	0.9346	0.8968	0.8784	0.9040
Grand Forks, ND	0.9299	0.9226	0.8896	0.9114
Grant, ND	0.9228	0.8925	0.9221	0.9173
Griggs, ND	0.9340	0.8806	0.8526	0.8900
Hettinger, ND	0.8750	0.9356	0.8909	0.8922
Kidder, ND	0.9224	0.8892	0.9228	0.9169
LaMoure, ND	0.9028	0.9093	0.9281	0.9147
Logan, ND	0.9107	0.8688	0.9262	0.9102
McHenry, ND	0.9243	0.8712	0.9005	0.9050
McIntosh, ND	0.9061	0.9023	0.9245	0.9133
McKenzie, ND	0.9252	0.9359	0.8963	0.9147
McLean, ND	0.8847	0.9199	0.9115	0.9022
Mercer, ND	0.9393	0.8753	0.8891	0.9068
Morton, ND	0.9248	0.9148	0.9125	0.9178
Mountrail, ND	0.8941	0.9418	0.8997	0.9047
Nelson, ND	0.9410	0.8589	0.8578	0.8913
Oliver, ND	0.9115	0.8852	0.9026	0.9032
Pembina, ND	0.9107	0.9446	0.9108	0.9166
Pierce, ND	0.9182	0.8860	0.9002	0.9050
Ramsey, ND	0.9257	0.8747	0.8489	0.8841

Table 5. *County level technical efficiency with NCI by major crop insurance shift: 1980-2014* (Continued)

County	CAT (1980-93)	REV (1994-99)	COV (2000-14)	Mean (1980-2014)
Ransom, ND	0.9115	0.9360	0.9097	0.9149
Renville, ND	0.8767	0.8759	0.8511	0.8656
Richland, ND	0.9337	0.9296	0.8858	0.9125
Rolette, ND	0.9247	0.8498	0.8707	0.8924
Sargent, ND	0.9049	0.9209	0.9209	0.9145
Sheridan, ND	0.8920	0.9032	0.8842	0.8906
Sioux, ND	0.9327	0.8537	0.9054	0.9075
Slope, ND	0.9013	0.9372	0.8987	0.9064
Stark, ND	0.9088	0.9150	0.8953	0.9041
Steele, ND	0.9194	0.9068	0.8844	0.9022
Stutsman, ND	0.9216	0.8978	0.9062	0.9109
Towner, ND	0.9183	0.8693	0.8766	0.8920
Trail, ND	0.9349	0.9305	0.8808	0.9110
Walsh, ND	0.9222	0.9363	0.9024	0.9161
Ward, ND	0.9183	0.9115	0.8771	0.8995
Wells, ND	0.9019	0.8873	0.8682	0.8850
Williams, ND	0.8664	0.9343	0.9127	0.8979
State Mean	0.9120	0.9008	0.8935	0.9021

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